AERIAL NAVIGATION

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AERIAL NAVIGATION

BY THE LATE

CHARLES BLACHFORD MANSFIELD, M.A.

OF CLARE HALL, CAMBRIDGE

AUTHOR OF 'TRAVELS IN PARAGUAY AND BRAZIL' 'A THEORY OF SALTS' ETC.

EDITED BY HIS BROTHER

ROBERT BLACHFORD MANSFIELD, B.A.

WITH a PREFACE by J. M. LUDLOW

London

MACMILLAN AND CO.

1877

LONDON: PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
AND PARLIAMENT STREET

AERIAL NAVIGATION

THE PROBLEM

WITH

HINTS FOR ITS SOLUTION

BY ITHI KEFALENDE

'Make thee an ark of gopher wood; rooms shalt thou make in the ark, and shalt pitch it within and without with pitch. And this is the fashion which thou shalt make it of: The length of the ark shall be three hundred cubits, the breadth of it fifty cubits, and the height of it thirty cubits. A window shalt thou make to the ark, and in a cubit shalt thou finish it above; and the door of the ark shalt thou set in the side thereof; with lower, second, and third stories shalt thou make it.' GENESIS vi. 14–16.

1851

THESE PAGES

ARE DEDICATED

TO THE

INDUSTRIOUS OF ALL NATIONS

'Men, my brothers, men the workers, ever reaping something new:
That which they have done but earnest of the things that they shall do:
For I dipt into the future, far as human eye could see,
Saw the Vision of the world, and all the wonder that would be:
Saw the heavens fill with commerce, argosies of magic sails,
Pilots of the purple twilight, dropping down with costly bales;
Heard the heavens fill with shouting, ...
From the nations' airy navies . . . . . in the central blue;
Far along the world-wide whisper of the south wind rushing warm,
With the standards of the peoples plunging thro' the thunder-storm:
Till the war-drum throbbed no longer, and the battle-flags were furled,
In the Parliament of Man, the Federation of the World.
There the common sense of most shall hold a fretful realm in awe,
And the kindly earth shall slumber, lapt in universal law.
So I triumphed, ...
. . . . all things here are out of joint,
Science moves, but slowly slowly, creeping on from point to point.'

TENNYSON, *Locksley Hall.*

'So er den Hammer hat, der meine Glocken schlagen kann.'

JACOB BEHMEN, *De Signatura Rerum*, cap. i. § 1, ad fin.

'Possunt etiam fieri instrumenta volandi, ut homo sedens in medio instrumenti, revolvens aliquod ingenium, per quod alæ artificialiter compositæ aërem verberent, ad modum avis volantis. . . . . . Hoc instrumentum volandi non vidi, nec hominem qui vidisset cognovi, sed sapientem, qui hoc artificium excogitavit, explicitè cognosco.

De Secretis Operibus Artis et Naturæ.
Cap. IV.—De Instrumentis Artificiosis Mirabilibus.
FRIAR BACON.

'Certainly many birds of good wing, as kites and the like, would bear up a good weight as they fly, and spreading of feathers, thin and close, and in great breadth, will likewise bear up a great weight, being even laid without tilting upon the sides. The further extension of this experiment for flying may be thonght upon.'

Sylva Sylvarum, Century 9, 886.
CHANCELLOR BACON.

'What next, I wonder!' said the hen. 'You have nothing to do, and so you sit brooding over such fancies. Lay eggs or purr, and you'll forget them.'

'But it is so delightful to swim on the water,' said the duck; 'so delightful when it dashes over one's head, and one dives down to the very bottom.'

'Well, that must be a fine pleasure,' said the hen. 'You are crazy, I think. Ask the cat, who is the cleverest man I know, if he would like to swim on the water and perhaps to dive; to say nothing of myself. Ask our mistress, the old lady—and there is no one in the world cleverer than she is;—do you think that she would like to swim on the water, and for the water to dash over her head?'

'You don't understand me,' said the duck.

HANS CHRISTIAN ANDERSEN, *The Ugly Duckling.*

PREFACE.

TRAVELS in Paraguay—A Theory of Salts—Aerial Navigation—the mere juxtaposition of these titles of the posthumously published works of the late Charles Blachford Mansfield indicates a no common breadth of mind. Each volume displays one of the aspects of a wondrously many-sided nature. The first showed his loving observation of nature, his keen observation of men. He was the first—it may be said, the only man—who recognised the singular energy and self-devotion of the little Paraguayan people, that energy which a few years later enabled its ambitious ruler to open up, with some chance of success at first, a desperate struggle against no less than three neighbouring states at once, two of them at least enormously superior to it in population, extent of territory, resources of all material kinds; that self-devotion which caused it to maintain the struggle to the point of virtual annihilation. The second volume was devoted to a branch of the science to which his working life was mainly devoted, chemistry; and, whether the conclusions it leads to are likely to be adopted or not, testifies to a careful industry, as well as to a strictness of reasoning, which are, perhaps, seldom found combined. The third, which unfortunately remained unfinished, will, I think, show in addition to the same careful

industry and strictness of reasoning, an imaginative power of the highest order. By imaginative power, I mean that power of realising that which is not seen—bringing out for oneself, and showing forth to others, its clear, visible image—which is the mark of God's true poets, whatever be the matter with which they work, words, tones, pigments, marble, or the wood, metal, chemicals, paper, out of which spring the spinning-jenny, the steam-engine, the daguerreotype, the photograph,—or, again, noblest of all, the nerve-cells of the human frame. As an inventor-poet, Charles Mansfield's gifts were, I believe, of the very highest order. There is not one of his published works which does not contain, scattered with a lavish hand, hints for the conquering of nature, which he left to be worked out by others; the notes to the present volume in particular, are rife with such. Those who knew him intimately—a now fast narrowing circle—recollect well how there would come upon him occasionally, after intervals of quiescence, a kind of divine *afflatus*, and for a time his mind would bring forth one device after the other in rapid succession, as those to whom the world restricts the name of poets multiply their works during periods of creative energy. The present volume is the fruit of one of these periods, and the words at the close of the author's preface, 'My object in writing it will be simply to deliver my brain of a burden which came upon it uninvited,' express, I believe, the strictest truth as to his mental experience.

If it be asked why, after the lapse of a full quarter of a century, an unfinished work by one who is no more on earth is presented to the public, the answer is, first, that the author himself wished to have so presented it when perfect, and that he was one of those whose wishes have a

right to be carried out as far as may be practicable. Secondly, that although the fact that he never completed it might militate against its publication unfinished, yet it does not appear that any publication issued since his death has in anywise taken the place which this volume was meant to occupy. Thirdly, that during the same interval events of high gravity in the world's history have shown that the question of aerial navigation may be one of life and death to a nation. For we have lived to see, what Charles Mansfield did not, France governed through balloons from besieged Paris, and a dictator who refused to despair of his country, cross the air over the heads of hostile armies.

It will be seen that the design of the present work is one which is of a nature to help whatever practical schemes may be put forth. Its subject is aerial navigation as a problem,—the determination of the conditions under which it may be ascertained whether the air is or is not navigable. The work indeed stops short in the midst of the most important of its chapters, that of the power sufficient for the propulsion of vessels through the air, which shall be genuine air-craft, and not mere gas-bubbles with a skin over them, as the present balloons. But even in this state it goes far to develope the author's views. And without pretending to the slightest mechanical knowledge, it appears to me that the severity of the method under which his inquiries have been undertaken must do much to clear the ground, by sweeping away, once for all, contrivances which are shown to be impracticable, and by indicating the directions in which really hopeful experiments may be prosecuted.

I have spoken hitherto of the work from a practical point of view only. Those who have eyes to see will recog-

nise in it much more than a severely careful and logical inquiry into a great mechanical problem. They will feel in it the stirrings of that high unselfishness which led Charles Mansfield to prosecute such an inquiry, at the cost of months of precious time, when it could bring to himself no possible advantage, and could only facilitate to others the means of acquiring money or fame. They will observe that deep spiritual insight, which, informed with very various scientific knowledge, delighted in tracing through all nature the finger of God; that genuine, self-sacrificing love towards his fellows, which only sought to master the forces of nature for the happiness of mankind. And they will mark how in his hands the whole subject is irradiated by a fancy, sometimes mystical, sometimes playful, which in Charles Mansfield was marvellously married to the two leading scientific faculties of accurate observation and abstruse calculation.

J. M. L.

The Editor wishes to express his gratitude to Mr. N. Story Maskelyne, F.R.S., Mr. F. C. Penrose, F.R.A.S., and Mr. Arthur Campbell for their assistance in arranging the appendices, and to Mr. Cornwall Simeon for his valuable assistance in preparing the work for the press.

AUTHOR'S PREFACE.

THE subject of the following pages is one that interests different classes of minds in various modes. Some look at it with a wary scepticism, doubting, perhaps, a little whether it be not presumptuous in man to treat it seriously; and doubting very strongly whether any human attempt to put such speculation into practice can ever be successful, or if successful, advantageous to our race. Some, and these are often persons whose knowledge of certain branches of science or of art entitles their opinions to respect, will only be restrained by decorum, from wording the fulness of their contempt for such impossible schemes and their silly contrivers, in plainer language than a gentle sneer. Others warmly express their enthusiastic hope that we shall some day add the air to our empire, and make no secret of their belief that the day is not far distant when invention will make another step towards conferring on the world one of the greatest blessings it could enjoy.

To the first of these classes I have no apology to offer. The third will require none. If to the second Lord Bacon's sanction—'the further extension of this experiment for flying may be thought upon,'—is not defence enough, I must ask them to reserve their judgment of the views I have to offer, until they have read them; and if

they find them worthless, not to be more severe upon my subject than they were before, but to heap all their condemnation on its treatment here.

As for the origin of this book, and my qualifications for handling its matter, a few words will perhaps not be out of place. Of myself this little will suffice, I have not graduated in 'Aerostation.' I never went up in a balloon, nor ever saw more than half a dozen in my life. I never had any passionate desire to fly, beyond a somewhat common wish to realise sensations known in dreams, with a notion, till lately only a vague one, that some day or other aerial navigation would be made practicable. I have not made, then, any long study of the question; nor are the following pages the result of laborious years in pursuit of a favourite scheme.

My attention was first directed to the question of aerial navigation, by a friend's pointing out to me a description in a French newspaper, 'La Presse,' of a monstrous balloon machine which it was reported was about to be built by subscription in Paris. The applause bestowed upon this cumbrous conception was evidence of a 'demand' for some such vehicle. The desire seemed reasonable enough, and was quite independent of the grotesqueness of the means proposed for its supply. This set me thinking on the matter: Surely if people will go such a way roundabout to solve a question, it may be worth answering. Is there really no simpler or more possible way of getting along in the air than this of M. Petins?[1]

A few minutes' consideration showed that the question was not complicated or difficult: Can or cannot a body be propelled through the air at a reasonable rate? The next swift that dashed by screamed 'Yes, verily;' and no

[1] See 'l'Illustration,' September 6, 1850.

theory which I had in hand could say 'Nay' to the bird. The general conditions requisite for the accomplishment of flight, and the means of satisfying them, spread themselves out at once before the fancy, and the details filled themselves in one by one in a few days as the scene became familiar. There were of course many points in this first crude sketch, which, on subsequent consideration, were erased as rough and untrue to nature; I hope that the opportunities offered by some months of reserve have matured the picture, and reduced it into tolerable form and harmony.

But has not all this been thought of before? Surely it must be all stale: and, by reason of some simple impediment which I overlook, impossible. This was to be enquired into: one must learn what had been proposed before, what had been essayed; why printed untried schemes, if such these were, had not been tested, and to what the failure of any actual attempts was due. Soon after it was announced that a new balloon was going up in London: new, patent, strange, and locomotive; and of course embodying all the latest improvements, if it did not solve the problem, and leave nothing more to be done. This of course was to be seen; from it one would learn all that was yet known about the matter, and whether there was any need of further inventions for its development. A glance at the machine was enough to satisfy one of the ingenuity of the projector, and of the utter inadequacy of the apparatus to the object proposed. This was staggering; clever men and persevering had tried and failed. But the causes of failure were obvious, the evident requisites had not been fulfilled—so there was room yet for progress. It appeared just then that there was much public interest in the subject of aerial propulsion,—articles in journals,

suggestive, encouraging, and recording one or two more attempts in the right direction, amid much sad gaping of crowds at men and ponies swinging from big bladders.

So the subject was to be 'got up,' beginning of course at the latter end, and working backwards—as is good in matters of History. Very few books were to be found treating the subject at all; the encyclopædias not generally very communicative on the matter; but a few pamphlets to be dug out of bookstalls, a specification or two in the patent records, a considerable number of papers in journals English and French, not much in other tongues. All this was to be waded through, to discover why we are still travelling by sea, and not by 'the ocean that comes up to every man's door.'

Of course I found many of my notions anticipated, sometimes single suggestions inadequate of themselves even to make a step towards success; sometimes complicated with other devices which in practice would frustrate their intention. I met, however, with very few accounts of actual experiments, none, of any, the failure of which could not have been predicted, or of which the insufficiency for more than a very partial result was not obvious. I found but one Englishman of any high scientific attainments who had given much assiduous and hopeful attention to the subject, and who, after having carefully examined all its difficulties and facilities, had given his judgment, that the navigation of the air is a possibility. The conviction of this gentleman, recorded nearly half a century ago, and often repeated since in scientific journals, was thus expressed in a letter to myself: 'I have no doubt whatever that I could at once put together a balloon that should carry its passengers at twenty miles an hour.' If Sir G. Cayley's untiring advocacy of aerial navigation, had ever

been met (when he proposed to form an Aeronautic Society) by any of the enthusiasm which assisted the Montgolfiers and MM. Charles and Robert to work out their project, there would have been no room by this time for such a volume as the present. I should state, however, here, that even Sir G. Cayley's scheme is not quite satisfactory to my mind: from the magnitude on which alone it was supposed by him to be practicable, and from an oversight in the proposed adjustments, which on experiment would have been fatal to its success at first, though it would no doubt soon have been remedied.

If this gentleman did not seem to me to have fully solved the problem, or to have stated it so that it could be at once solved on mechanical trial, assuredly no other projector has, so far as I can learn, shown how a true navigation of the air may be effected. It was not till after I had completed my own views of this matter, and had become pretty well acquainted with former schemes, that an experiment was publicly made in Paris by a poor working man, which went further to clear the way through the air than has yet been shown. But it did not go far enough into the matter, and left untouched the vital point —the motive power—the foundation for which most aerial schemers had forgotten to provide, scarcely anyone but Sir G. Cayley has attempted to secure. It seemed then that the field was still open.

But, besides the enquiry as to how the main question stood, it was necessary to ascertain what data were already to be found in our stores of knowledge, from which the amount of difficulty to be overcome, and the means at hand for meeting it, could be at once stated and compared. Very few such data are to be found: absolutely none on the most vital points, except generalities, all promising

success. It is indeed somewhat remarkable that scientific men should have been so long contented, as they have for the most part been, with assuming that aerial propulsion is impossible, not only without making any attempts to demonstrate that it is so, but without trying or even quoting a single experiment at all applicable to the purpose upon the most important condition in the problem—viz., the Resistance of the Air.

The result then of my enquiry was, that I could not learn from books that my notions were either ancient or impracticable. But in the absence of exact data, from which the problem might be calculated to precision, experiments were to be made to obtain them: and it would have been infinitely more satisfactory to me to have put forth what I have to offer, in the form of numerical results of careful experiment, than to have uttered them as mere suggestions.

The impediments to my wish have been twofold: Firstly, the expenditure of time and money too great for my limited means, yet necessary to the extortion from nature of a full and exact answer as to certain conditions on which accurate details are preferable to general certainties. Secondly, the fact that when I had selected two or three special points for personal examination, I was disappointed in the pursuit of the study by failure in the completion of the apparatus ordered for the purpose, partly by mistakes, partly by delay in the execution. So that after six months passed now in patient waiting, now in exhortation to speed, I have been obliged to content myself with pointing out the lines and modes of enquiry which I consider necessary and sufficient to prepare a fair start for the navigation of the air.

If any person—physicist or engineer—should conde-

scend to read these pages, and should conceive that some better apology than this is due to him for venturing into print without new experimental results, and elaborate mathematical form of proof; he must please to take these considerations. Firstly, that myself to try all the experiments which suggest themselves would have been impossible; and that not to try to put others in the way of doing what oneself cannot accomplish, is not the most patriotic plan, and not the one which Bacon followed, though it may be the most scientific. Secondly, that calculations founded upon imperfect data, cannot give numerical results worth anything, though they may be very amusing to those whose talent lies in figures and symbols, and very likely to give an air of profundity to reasoning that may be but shallow; or like the coating of a bubble may have no bottom at all to rest on.

Finally as to the object of my book, I cannot exclaim in legitimate prefatory style, that if I shall have succeeded in awakening in one bosom the love, &c., &c., or in inducing one more competent than myself to take in hand, &c., &c., for the benefit of humanity, my wish will have been fulfilled. I do not entertain either of these wishes very fondly, though I should be very glad of either result, of the latter especially. My object in writing it, will be simply to deliver my brain of a burden which came upon it uninvited, and which will not quit it at my bidding without receiving leave to rush into the press.

CHARLES BLACHFORD MANSFIELD.

March 18, 1851.

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Errata.

Wherever the name 'Marcy Mongé,' or 'Morge,' occurs *read* 'Marey Monge.'

Page 8, line 13 from top, *for* 'la' *read* 'le.'
" 17, " 23 " *for* 'vigoreuse' *read* 'vigoureuse.'
" 29, first line of note, *del. first* 'with.'
" 32, third line of third paragraph, *for* 'hence' *read* 'have.'
" 54 fourth line of note, *for* 'fillet' *read* 'filet.'
sixth " *for* 'de ballon' *read* 'du ballon.'
seventh " *for* 'de' *read* 'du.'
" 88, eighth line from top, *for* 'principle' *read* 'principal.'
" 94, seventh line from bottom
" 95, fourteenth " *for* 'Beaufay' *read* 'Beaufoy.'
" 129, seventeenth line of note, *for* 'Monk,' *read* 'Monck.'
" 149, last line of first paragraph, *for* 'T' *read* 'I.'
" 156, twenty-first line from top, *for* 'raissonnerait' *read* 'raisonnerait.

AERIAL NAVIGATION.

GENERAL INTRODUCTION.

WHETHER the word aerostation means really the aerial science, or the stationary art; or whether, as a friend suggests to me, it refers to aerial stationery or paper of which the first balloons were made, I must leave it to the dictionaries to determine. What it ought to mean, and what it seems to mean, however, I shall here note, as it has been occasionally applied to the subject of which it is my especial object to treat, and to which it is no ways appropriate.

Now as to what it ought to imply. This is of course the practice with, or use of, an aerostat. The question, therefore, becomes—What is an aerostat? Let it not be interpreted by the custom of its similars. Now the usual and right acceptation of these foreign substances ending in 'stat' is instruments for keeping something steady; thus a 'rheostat' is a contrivance for maintaining a voltaic current at a required strength, and a 'heliostat' one for making the sun stand still. An aerostat therefore ought to mean a machine for keeping the air quiet, and aerostation would be the art of doing so. A very valuable machine and very desirable art, held no doubt once by Scandinavian witches, who used to still the storms and sell the winds to the Norse sea-kings, but a machine and an art that we have not just now in Europe, though we may some day get them.

Next, as to what aerostation seems to mean. It must in this be judged by vulgar use. It is most commonly applied to a popular amusement prevalent at tea gardens, wherein a large

globe filled with light gas ascends into the air with the appendage of some animal. On the first occasion [1] when this was practised, a sheep, a cock, and a duck were the victims; this was for the edification of a king; but since that time, the enjoyment of the people being concerned, a woman, a horse, a tiger, or a man, at least is requisite for the sport. And very good sport it affords—for the winds. This aerostation then seems to designate in pseudo-classical language that which is called 'ballooning' in our mother tongue—an art or practice relating to the air, and which has remained quite stationary without a single improvement of any worth from its first invention till now.

Now the matter which I have in hand—aerial navigation or aeronautics—has nothing to do in its present stage with either of these meanings of this word, either with the proper or with the apparent. From the latter it has derived all the hints it could obtain, and it does not yet aspire to the possession of the former. I shall therefore not adopt this term at all.

For the word 'balloon' I shall have but very little use, and that only in speaking of the early attempts made to take advantage of the services of light gases for the purpose of travelling through the air. I shall use 'balloon' always in its true sense, or in one varying very little from the right application—that of a globular vessel. I shall use it always to indicate a receptacle for gas, either spherical, or of some form not differing much from a sphere, such as that of a pear or an egg. When speaking of a buoyant envelope of a form appropriate to locomotion through the air, I shall use the general term 'gas-vessel,' which is equally applicable to all shapes, and is at least not suggestive of an absurd one. In treating of the part of an aeronautic apparatus destined to contain the voyagers, I shall not use the term car—a clumsy toy which I shall leave hanging to the balloon—but shall adopt 'galley,' 'boat,' 'man vessel,' or some word which need not remind the reader's ears or eyes of Irish roads or a clothes-basket. Air-craft seems an appropriate term for the whole apparatus, including boat and gas vessel, or car and balloon.

I shall divide the consideration of my subject into two parts:

[1] Sept. 19, 1783, at Versailles.

the first containing the enunciation of the terms of the problem; the second embodying such limits as seem to me necessary and sufficient with the aid of current knowledge for its solution.

In treating of any art or science, it is a frequent practice to preface its technical discussion with an historical account of its development. Such narrative is generally useful and always interesting, and I believe that in the present case it would be peculiarly so—not as tracing the steps by which we have progressed to our present position of success or of promise, but as showing the singular blindness which has affected the human mind in its eager struggles for a possession which it has always vaguely fancied to be its inheritance, and which it seems to have felt was falling due about the approaching period of its maturity. However, though the inventions of Montgolfier and Charles seemed to place this treasure within the reach of our race, it has hitherto been kept back from us, perhaps as not yet being discreet enough to be trusted with the boon. It is not a little remarkable that in this age of applied science, very little inventive talent of high order has been brought to bear upon this subject. Some idols of the forum have drawn off the attention of most of those who might have assisted the perfection of the art; want of co-operation has baffled the few who have seen and pointed out the way towards its improvement. The history then of its progress or standstill would not display a series of brilliant failures, or of partial successes, but rather a number of attempts sometimes vigorously urged, but ill directed; sometimes well conceived, but wanting aid to carry them into effect.

Such then is the aerial navigation of the past. It was a part of my original plan to have endeavoured to give an account of these past struggles of the giant in his cradle, but want of time and more important occupations have compelled me to leave this task to those who feel more inclination to look back into the past than to go ahead. I shall, however, interweave into the texture of my essay such notices of the bygone schemes and failures of the would-be air sailors as most fully illustrate the propositions which I have to lay before the reader.

The first part then of my book will state the present condition of the question, it will examine what those who have gone

before have left for us now to do in attacking the problem, and what are the necessary conditions that must be satisfied in any attempt to solve it.

The second part—that which it is my chief object to produce—will explain the means by which I believe that in the present state of science, by simply using the materials and appliances which we have now at hand, without waiting with folded arms for more discoveries of the secrets of nature, we may at once, if we will buckle to the work, take possession of the realms of air, and travel through them at our will. I shall consider separately each of the requisites already ascertained in the first part, and shall endeavour to show that every one of them may be now fulfilled, that there is no difficulty in adapting to each of them materials which we have long had in our stores of treasures won from nature; and that nothing is necessary to make aerial navigation a reality, but a little co-operation in setting the results to work. Not that experiments are necessary to establish the positions I shall maintain; there is proof enough of them in general facts, which may be found in every text-book of science: the experiments are only wanting to obtain the precise results necessary to facilitate the construction of apparatus in the manner most favourable to perfect success.

According to the original plan of this book, I had intended it to have consisted of three parts: the first of these was to have been historical, treating of the past endeavours of those who have preceded me with the pen, and with tools more likely to the work; the second was to have discussed the present condition of the problem, to have prepared the ground for the third part by stating the requisites to be fulfilled, deducing them partly from theory, partly from the suggestions of the historical division; the third part was to have treated of the future prospects of the art, detailing the means by which I believe the problem is to be solved. I have been compelled to omit altogether the first part so contemplated by want of time to complete the compilation. I was anxious to finish the book as soon as I could, partly for the purpose of getting the subject off my mind as soon as possible, and partly with a desire to throw the burden of it upon the minds of others during this summer of 1851, which is to be

an era in the progress of scientific industry. The second part of my intended triad forms the first part of the book now in the reader's hands; I shall, however, throw into the theoretical discussion, of which this division would have consisted in my original plan, a quantity of historical matter by way of illustration, which will to some extent supply the want of the first part. I shall with this view make my quotations from those who have gone before us, with especial reference to time and place, and as much as possible in the order of historical succession; that the reader, if he derive from my pages any notions as to the order of time in which the various schemes have been proposed, may, so far at least, be furnished with correct information. The second part of this volume is exactly what would have formed the third part of the first design.

If, however, my historical part had been written, it would have been no account, as is usual in the preliminary treatment of technical matters, of the gradual growth of an art. The only history which could yet be written of aerial navigation could not be dated from its birth, since it is not yet born, but could only treat of the pulsations of its embryo life. No collection of the records of these have ever been compiled; if it were made, it would, independently of the utility or interest which it might have for those who should have a fancy for the art specially, or in human attempts at progress generally, certainly be an amusing history. Men of the future on reading would wonder how men of old could fumble about so long without at once putting it into shape, seeing that it is so simple. It must be remembered that ballooning, or the practice of floating in the air, is not here spoken of, but Aeronautics, or the Art of travelling through the air. Of the first recreation numerous annals may be found, in which every incident in the adventures of the 'aerostatic globe' have been collected, with the names of all the 'intrepid aeronauts,' gentlemen and ladies, 'with oak and triple brass about their hearts,' who have heroically paid or received five pounds apiece and essayed whither the winds would waft or hurl them. Such a catalogue will be found by those who have a fancy for these exploits, along with much really interesting and useful matter, in Mr. Monck Mason's 'Aeronautica.' It is with the second

only, as a useful art, that I have to deal, and in retrospective comments that I shall have occasion to make, I shall touch solely upon such experiments and suggestions as have been made for the purpose of aiding in the achievement of a real conquest of the air. It is of these that I think a history would be valuable, as filling a gap in the literature of the subject, and as supplying a want I have felt myself in my own enquiries.

Of course the early notions of, and attempts at, mechanical flying, would most properly find a place in a complete history of this embryo art. And though these failures would be full of interest, if we had any materials for a good account of them, the historian would find but little record of them beyond the number of limbs broken by each of the enthusiasts who have made their struggles in the air. Of their mechanical devices, there are, with few exceptions, no record for the guidance or warning of the future experimenter.

I shall have no occasion to allude to these, for, as I have said, my object will only be to show that flight by aid of buoyant floatage is possible. My notice of former aerial schemes will be limited therefore to attempts towards the propulsion of gas vessels through the air.

Several authors who have written the history of balloons have opened their subject by endeavouring to trace first dawnings of the life of the art from the early records of human tradition, through the speculations and even attempts of the last few centuries down to the great era of the balloon. These would properly be included in a summary of the development of aerial navigation. Among them are some curious instances of those anticipations of modern discovery which, visionary or real, were so common among the learned monks of centuries less clever than our own; I shall have occasion to allude to one or two of these foreshadowings of the balloon. The author who has treated most fully cf these attempts and imaginings is M. Bourgeois, whose 'Recherches sur l'Art de Voler' appeared soon after the publication of M. Faujas de St. Fond's account of the first experiments of the Montgolfiers and of Charles and Robert. To his industry, indeed, it is probable that all the other authors who have written on the subject owe most of their facts and stories about

the efforts to fly made before the advent of the balloon. This ancient yearning of the human mother mind for aerial offspring would form an interesting preliminary chapter, the mythical part, as it were, of the narrative; but the era from which aerial navigation will always date its history is the day when Montgolfier's invention, fertilized by the discovery of Cavendish, came forth as the huge round egg, in which, after seven decades of years of incubation, the great bird of the future is now lively and stirring, soon perhaps to break forth to its work in the restless world. The last seventy years will be the main field for the historian of the embryo art; he will find his work among the schemes for, and attempts towards, the propulsion of balloons and other gas vessels through the air. He will meet however within this interval with some noteworthy endeavours to solve the problem of flight without the aid of buoyant matter; I shall give a list of books and papers from which much of the materials for this, as well as for the rest of the subject, may be obtained.[1]

The historian will not discover among the signs of activity, which the yet unhatched chick has exhibited, many promises of a very vigorous organisation for its future life: he will however find traces of some efforts at vitality which will give him hope. These struggles in the egg are what I shall have to notice in illustration of the fundamental propositions by working upon which I shall afterwards seek to assist in its escape from its shell. It will be observed that the projects to which I shall make reference are almost exclusively French and English; I have not met with any mention, in the authors I have consulted, of any German efforts to improve upon the balloon: and I have succeeded in finding but few accounts of endeavours in this direction which have been made in Italy. The French have been very active at different times in their search for the solution of this problem, which to them must have something in it of a national character. The sort of feeling with which the invention of Montgolfier, and the application by Charles and Robert of Cavendish's discovery of hydrogen, was hailed in France, 'le vrai motif qui enthousiasmait tant ce peuple de

[1] See Appendix A.

France,' as the author of a recent French sketch of balloon history[1] expresses it, may be gathered from the following lines which were current in Paris at this remarkable period:—

> Les Anglais, nation trop fière,
> S'arrogent l'empire des mers;
> Les Français, nation legère,
> S'emparent de celui des airs.

'Ce qui flattait surtout la nation,' continues this author, quoting 'Le Journal d'un Observateur,' 'c'était de précéder les Anglais, cette nation rivale en tout, dans les sciences comme dans la guerre, et de la précéder dans ce qui paraissait alors avoir une immense portée, un avenir aussi fructueux dans résultats matériels, que glorieux dans la mode de procéder.' An honourable rivalry, perhaps, in the endeavour to be foremost in conferring benefits on our race. But nothing has come of the competition. Balloons are still as useless as on the day of the first experiment at Annonay. It remains to be seen whether efforts in which the two nations may take part in concert, may not yet be made with more success to achieve the conquest of the air. However, the French of course have produced many schemes for this end, some in the early days of the balloon, some in these latter years. Of several of these I shall have to make mention: one or two of them I find to be egregiously absurd; but on the other hand, by far the best experiments that have been tried yet, so far as I can learn, and to which I shall specially direct attention, have been made in France by a Frenchman. I shall try to deliver any conclusion as to the value of any contribution towards the end which I am seeking, with equal justice, whether the author of it be Briton or foreigner. I shall have to refer to a few actual experiments made on a large scale, to some notions that have been tested with models, but principally to hints or schemes, embodied like my own only upon paper. I shall be careful always to make distinction between these different degrees of poetic dignity: an important point which is not always attended to by describers of inventions.

[1] Turgan, 'Ballons,' p. 33.

I shall thus endeavour to place the reader on the ground from which aerial navigation has now to take its start, by showing, through considerations deduced from simple principles, what are the requisites which must be fulfilled. In doing so, I shall illustrate each portion by instances of attempts made by former schemers, and by quotations from former writers, thus showing the opinions which have usually been entertained on the conditions of this art, and of the means of fulfilling them. In doing so I shall have to point out a few instances of happy device, and of correct reasoning, but a far greater number of mistakes in conception, and of blunders in design. I shall generally select for remark such projects and treatises as either having been put most prominently forward, have had the greatest share of public attention from time to time, and are therefore most likely to be familiar to the reader, or such as being of the most value ought to be brought before him, if they were not already known to him. Where some experiment or suggestion less commonly known is adduced as an example, it will be either on account of some peculiar excellence in the thought, or of some curious vagary of inventive fancy which bears on some peculiar point of theory or practice. I trust that in the criticisms which I shall of necessity be led to make, I shall give to the best of my ability an impartial judgment as to the worth of the design or view which is under notice.

AERIAL NAVIGATION.

PART THE FIRST.

STATEMENT OF THE PROBLEM.

'Certainly many birds of good wing, as kites and the like, would bear up a good weight as they fly, and spreading of feathers, thin and close, and in great breadth, will likewise bear up a great weight; being even laid without tilting upon the sides. The farther extension of this experiment for flying may be thought upon.'

Chancellor FRANCIS BACON, 'Sylva Sylvarum.'
Century 9, 886.

CHAPTER I.

INTRODUCTORY.

In seeking the solution of any problem, the first step to be taken is to get a clear and fair enunciation of what it proposes. This may sometimes be attained in a few words. In the present case this is impossible. General readers can be but little acquainted either with the amount or with the kind of difficulties with which the road to aerial navigation may be obstructed. Scientific men generally have abstained from enquiring about them. These impediments, though at first sight apparently many, may yet not all be equally obvious at once; some again of the supposed obstacles may vanish on closer inspection. It is therefore necessary to the statement of the problem that a detailed examination should be made of the circumstances under which it is proposed. Such then is the subject of the first part of my book; I trust that I shall have omitted nothing that is necessary to be considered in determining the conditions that must be satisfied.

The end that is to be attained is the rapid movement of heavy solid bodies through a light elastic fluid—the atmosphere. The discovery of gases lighter than the ordinary air, has started the question for us under a new form, in which it could not have presented itself to the mechanical, though it did to the verbal, poets of former centuries. So that there are two possibilities to be considered in respect to aerial propulsion, according to the means by which the weight of the human body is to be sustained. The first case is, if the lifting power be derived from mechanical force applied to the air, either by the muscles, or by some artificial source; the second, when the weight is neutralised by a buoyant counterpoise.

I shall commence by showing that the common objection usually made to the accomplishment of these two methods by human muscular effort is unfounded. This is necessary, because it is the elementary form of the problem, man being, of course, a lighter and simpler mechanism than man plus engine. Taking the first case in its simplest form, that of the flight of a single man by wings attached to his body, I shall endeavour to show why it should not be dismissed from the mind as an absurd impossibility. I believe the light in which I have endeavoured to exhibit the prospect of success or failure in this matter, is new, at least I have not met elsewhere with a similar illustration of it. I shall not pursue the question of mechanical flight further by discussing the feasibility of an aerial machine, which might be raised from the ground and propelled solely by the muscular effort of a man, by the joint labour of several, or by artificial power; for this is foreign to my purpose, which is to indicate the road to success in the second form of application. I shall there show why, of the alternatives thus presented to us, I have chosen this latter, of which the balloon has given the hint. The impossibility of propelling the balloon is naturally first to be pointed out, and the objections to be noticed, which founded upon this have been urged against all attempts to guide the course of gas vessels through the air. I shall have to show how far these objections are groundless, how far they are valid and have to be combated. This leads us to ascertain the first condition which is imposed on us by the necessities of the case, and of which the faithful fulfilment is essential to success.

Out of the consideration of this preliminary requisite, the ascertainment of other conditions will flow in regular order. I shall have then to consider each of these separately, as they come before us under the heads of each. I shall briefly recapitulate the methods by which such former projectors as have come nearest to the mark have sought to surmount the difficulties that presented themselves; and shall show why their shafts have missed or fallen short of the target, and, perhaps in the case of one or two of the requisites, shall have to show that the inventors and experimenters have failed to take any aim at all. This prepares the way for the means by which I shall propose to satisfy the

conditions, and which will form the matter for the second division of the book.

I hope that this first part will form a clear statement of the condition in which those who have gone before me with the pen, or with tools more worthy, and more likely to the work, have left the ground of aerial navigation, and in which we find it now. It will thus be my endeavour to lead the reader step by step towards the belief, which it is the purpose of these pages to expound, and for which in the second part I shall establish the foundation. I should not have put together this long preparatory statement of the problem, if I had met with any complete treatise on the condition of this art. The only writings on this subject that I am acquainted with in our language, as having for their purpose to give a view of its requisites, as at present ascertained, are the 'observations' at the end of Mr. Monck Mason's 'Aeronautica;'[1] and a paper by Sir George Cayley in the 'Mechanics' Magazine,'[2] to which I shall have frequent occasion to refer. But the former of these is in some respects deficient and unsatisfactory, and the latter is, from its brevity, necessarily incomplete. In French aeronautic literature, which, the subject being with them a national one, is far more copious than our own, the only attempt at a full examination of the subject, under the light of modern science, that I am aware of, is that of M. Marey Monge in his 'Études sur l'Aerostation.'[3] But this interesting and well arranged work contains some grievous errors, which quite destroy its value as a standard of reference.

[1] Pp. 291–349. [2] Vol. xxvi. p. 418.
[3] Pp. 1–181, 1837.

CHAPTER II.

THE PROBLEM OF FLYING.

To FLY or not to fly? that is the question; with aid of buoyant gas or without? How then is the problem stated? Let us hear what the most respected authorities have laid down upon the subject. Borelli, who is so often quoted in his work 'De Motu Animalium,' published at Rome (1680), says, 'in enquiring, therefore, whether men can fly by exertion of their own strength, it must be ascertained whether the motive force of their pectoral muscles (of which the size is the index and measure of their power) exceeds in the same degree (as in birds), viz.: by ten thousand times, the resistance of the weight of the entire human body, together with the weight of immense wings, which must be fitted to the arms.' [1] And we find the 'Encyclopædia Britannica' thus delivering judgment: 'The application of oars may turn a balloon, but can have no sensible effect in directing or impelling its course. How vastly disproportionate is the force of the human arm to the overwhelming pressure of the wind against so heavy a machine! To adapt machinery under these circumstances would be preposterous, and to look for help from such a quarter is visionary in the extreme.' [2]

Now neither of these positions represents the true state of the case, or anything the least like it. Old Borelli certainly never

[1] Quando ergo quæritur, an homines propriis viribus volare possint, videndum est, an vires motivæ musculorum pectoralium (quorum vires indicantur et mensurantur a vastitate eorundem musculorum) eodem excessu, scilicet decies millies, superent resistentiam ponderis totius humani corporis una cum pondere ingentium alarum quæ brachiis aptari debent.—Cap. xxii. prop. 204.

[2] Encyc. Brit. 7th ed. 1830, vol. i. p. 104.

studied at an English University, neither probably did the learned Encyclopædist, or, if he did, his studies must have been confined to his books, and he must have grossly neglected the opportunities afforded him of studying practical dynamics on the river. The mistakes of the former author are excusable as coming out of Rome in the seventeenth century; but an Englishman in the nineteenth ought to have known better. Did any gentleman who is fully convinced by this triumphant reductio ad absurdum that aeronautics are impossible in any shape, ever happen to pull in a boat? If he has taken that exercise, did he ever find that he could do much work with his arms alone?—if so he may congratulate himself on his very extraordinary vigour about the upper extremities. The last sentence of the paragraph I have quoted from the Encyclopædia is simply a bold dogmatic assertion, which I shall not combat now; but if the reader rests any faith on it at present, I hope my future pages will induce him to change his mind. Nov I must confess to not having read Borelli 'De Motu Animalium,' and after consideration of the famous passages which I have quoted, I do not feel at all inclined to study his previous arguments; and I hope I may be excused in doing so, as they have no bearing upon the question I have in hand. Bourgeois, who innocently remarks, 'Borelli a fait cette démonstration d'une manière sevère et vigoreuse,' has printed the chapter in which Borelli discusses human flight, and from his quotation I have extracted the passage.[1] I simply cannot conceive what he means by the force of any muscle in any bird exceeding by ten thousand times the weight of the whole body of the animal.[2] Suppose an eagle weighs ten pounds, can any one seriously believe that the pectoral muscle of that bird would sustain for an instant a weight of a hundred thousand pounds; it would probably be nipped from its attachments, or rent asunder by a hundredth of the weight; that it could contract against

[1] Bourgeois, 'Art. Vol.' p. 72.

[2] In the paragraph preceding that from which I have quoted the above sentence, Borelli says, 'Quia vis motiva alarum in avibus ostensa est decies millies major, quam sit resistentia ponderis eorundem,' &c. He must have got to this by some prodigious dynamical fallacy.

such a force is a notion almost too ludicrous to be mentioned. But it is not worth while to examine the grounds on which Borelli makes his extortionate demand for power before he will consent to fly. For the position which he assumes in the very clause which I have quoted is altogether a false step. It does not follow that because birds fly with their pectoral muscles, therefore, if a man was to fly, he would trust to his arms to sustain him. It is very curious that he should have made this assumption, and have been so gravely listened to while he descanted on it. He must have known that fishes swim by means of their tails, and that dogs do not, but paddle with their legs. He must have known that a monkey will hold a nut in his forehand, while a parrot will grasp a morsel with his hind one. Good old Bishop Wilkins was a better physiologist than this: we will see presently what he says on the subject.

Before taking leave of Borelli, however, I must do him the justice to state that what he goes on to say, in demolition of the puppet he has set up for himself to knock down, is rather more rational, if not more to the purpose. 'The weight of these muscles in birds that urge the wings is not less than a sixth part of the weight of their whole body; but the pectoral muscles of a man do not amount even to the hundredth part of his entire weight.'[1] Let the Bishop answer him.

'But now because the arms extended are but weak and easily wearied, therefore the motions by them are like to be but short and slow. It were therefore worth the enquiry whether this might not be more probably effected by the labour of the feet, which are naturally more strong and indefatigable, in which contrivance the wings should come down from the shoulders on each side; but the motion of them should be from the legs being thrust out and drawn in again one after another, so as each leg should move both wings, by which means a man should, as it were, walk or climb up into the air; and then the hands and arms might be at leisure to help and direct the motion, or for

[1] In avibus pondus musculorum alas flectentium non est minus unâ sextâ parte ponderis totius corporis ejus. At musculi pectorales humani nec centesimam partem ponderis totius hominis æquent.

any other service proportionable to their strength; which conjecture is not without good probability.'[1]

Not without good probability, I believe, and will endeavour to show grounds for that belief, though I do not undertake now to demonstrate its possibility. Assuming then Borelli's proportion to be the correct representation of the relation between the weight of a bird's flying muscles and that of its body; and assuming, with him, that such weight of muscle at least (one sixth of the weight of the body) must be available for the purposes of the wings in any animal that is thinking seriously of flight, the question for us men would not be at what fraction our pectoral muscles should be valued, but whether we have not other muscles about us which would make up the required amount. But I am not going to enter into any anatomical discussion of the matter, for this would at best lead only to a theoretical notion about it one way or the other; the observations which I wish to make are practical, and my suggestions will be for experiment.

However, before quitting the ground of speculation on which men are so apt to linger, and mounting into the higher regions of fact, I must state that I am convinced (on grounds which will hereafter appear) the amount of power put forth by birds is enormously overrated by most of those who have considered it, not of course with respect to the weight they support, but as to the resistance from the air they have to combat. But I must add that Borelli does not take sound premises in starting from a comparison of muscles, weight for weight, or size for size. It is, indeed, most likely that he has by no means made out the best case for his own position. The force of muscles cannot be estimated by their size alone, far less can any valid comparison be made in this respect between the parts of animals of different orders, between creatures whose physical economy is so different as that of a bird is from that of a man. The duty (to borrow a steam word) of muscles depends upon the amount of material for power which they are fitted to consume when it is supplied to them; this comes to them in two forms, firstly as nutrition direct

[1] 'Math. Mag.' Book 2nd, Dædalus, chap. 7 (5th ed. 1707, p. 121), 'Concerning the art of flying, the several ways whereby this hath been, or may be attempted.'

to their substance (composition); secondly, as nervous energy (decomposition)[1] imparted from the brain and spinal marrow,

[1] A great deal of confusion prevails in our minds about animal existence, and is kept up in learned books and common talk by the loose and undefined use which is made of the terms vital force and life; as if we men were provided with only a single such faculty or property. Now the fact, is, that, though we cannot all claim to be as well off as a cat is commonly said to be in this respect, we have, or rather perhaps are, each of us three separate lives; these are not successive but simultaneous, and form together one indissoluble whole. One of these, as in all true trinities (of the infinite number of which that make up the universe, man is the most perfect that is visible), proceeds from the other two. For a geometrical illustration of this I must refer my readers to the chapter and diagrams in their mechanical textbooks on the composition and resolution of forces. Our three lives, then, are the nutritive, the volitive, and the motive; the creator, the destroyer, the preserver, or in plain English, which is better than Latin or Hindoo, the nourishing power that builds up the body, the mind that uses it up, and the motive force that keeps it going. To anatomists and others, who believe in the existence of matter, I should speak of the plexus solaris, the cerebrum, the mylon;[a] and should probably amuse them very much. I am not going to show that each of these unities is itself a trinity, which would not be difficult; but to point more precisely to one side of the relation that binds them together. I have said that one proceeds from the other two, by which I mean that one depends upon two, being without them, powerless—nothing. I did not say that only a particular one stands in this relation to the other two. I will however show, which is all I require for my present purpose, how one of these is connected with the others by this tie of binary dependence, forming with them a true polarity, realising another of the great laws which pervades the physical world; the mutual dependence of two forces acting in opposite directions, not in antagonism, but in inseparable amity. The two faculties of voluntary power and of involuntary energy, both of which in great part issue in movement, the latter chiefly so, are exercised in the using up of the materials of which the animal framework is made, these two may be summed as one kind of life—the decomposing or animal force. The former is ever resupplied by the feeding or nutritive life, which repairs the exhausted brain and muscles by its industrious building energy. This latter is another vital force, the composing or vegetal life, without which the former is of no effect. And this latter in its turn is dependent on the motive faculties for its means of work, for the food which it has to convert into flesh. The two

[a] 'Mylon,' *sic* in MS. Possibly 'Myelon' (μυελός, moelle, marrow), a term used by Owen for the *medulla spinalis*, was meant to have been written.—Ed.

for which second requisite the muscles are indirectly indebted to the food. The question is one of rapidity of action; of intensity as well as of quantity. It is no doubt a fact, that in the animal machine a given amount of food cannot be made to yield more than a given amount of power. Now it is very likely that such birds as really do much work, approach the maximum in the amount of force they get out of their fuel; they probably do full justice to their victuals. But whether they do so or not, it is quite certain that men do not take out of their food as much service (in any shape, animal, moral, or intellectual) as they might. At any rate, the really flying birds, those of nervous temperament (of course a lymphatic turkey or auk is not a subject for the comparison), such as swallows and falcons, live much faster than we do, consume a far larger proportion of food (weight for weight per day) than we do, and devote the whole of it to their one business of restless flight. In short, there is little doubt that their muscles are much more vigorous than ours in proportion to their size and weight, whether of arm or leg. So Borelli did not take of his false position all the advantages it would have yielded him.

But returning to our legs, let us see what indications we can find of any chance of success in flight by using them as our propellers. Let me remind the reader that I do not undertake to prove that a man can fly a yard—though I think it not impossible that more than that may have been proved already by experiment on one or two occasions—with and without expense of human bone. I only wish to show why I think it most likely that, if he set to work in the proper way, he might move through the air without any support but what the air and his own muscles might afford him, to a distance or a height proportioned to

are distinct and opposite. Yet one—a true polarity. It is the first which we see working in the bird's wing; but the second works unseen, and it is the intensity of both which is measured by their great activity; by the work they do, and the food they consume. There is a just balance between them proper to each individual among man and the animals that attend him—to each species among the tribes that are free. Each is worked for and by the other: if the one is overworked, the other suffers. But this birds never do: 'Il faut manger pour vivre, et non pas vivre pour manger.'

his strength of limb. I do not think it impossible that some men might thus progress through the air at a rate of speed useful for some purposes; but I do not think they would do so till a great many experiments had been made in concert by the joint ingenuity of many minds. And I do not think that even then they would make much way unless they put themselves into the best bodily condition, and kept their muscles in good training for the exercise. Men cannot row in a boat with effect if they do not do this, and it is not likely they would fly without it.[1]

Now the first thing to be done in flying is to raise oneself from the ground; if one can do that a step may be made, without it none is possible.

Can a man raise himself from the ground by his arms? If the schemers in flying, or their critics, had considered this question they would have saved themselves a great deal of trouble; the first in vain practice, the others in theorising. Most men can raise themselves into the air by their pectoral muscles and those of their arms—some cannot do it at all, they are too heavy; many cannot the first time they try, for this like any other exercise requires some knack in the application of the strength. The point is to be ascertained by first hanging freely by the hands from a fixed horizontal pole, with the feet off the ground, and then trying by bending the arms to raise the body. I have seen two persons, a gymnastic master and a tumbler, who can do this with one arm, but they were men with herculean chests and arms, and very small bodies and short legs—not built upon the Caucasian model. I believe such men as these might fly with arm wings. However, ordinary men in good condition can raise themselves from the ground by their two arms. But how far? —that is the point. They can lift their chins to the level of the beam from which they may hang, and letting themselves down,

[1] If any lady sighing for the wings of a dove, should wish to know what likelihood there is of her cleaving the air with pinions of her own, I must refer her to the lady-glowworm, who is content to shine at home with her peculiar lustre, while her lord spreads wings for his work abroad, and to the industrial association of ants, where the females, having by birth wings, make a point of cutting them off, that they may attend to their domestic duties, and leave the flying to be done by the gentlemen.

can repeat this a certain number of times in succession without rest; few men can on first trial get beyond a dozen, or even after some practice exceed a score, their muscles becoming more and more exhausted after each exertion. Now, supposing that on each such lift our man rises through two feet, and that he can repeat this twenty times in succession, he will raise himself altogether through forty feet by the use of his arms. However, it is probable that his force is not used to best advantage throughout the whole of each effort. Perhaps it may be supposed that the most is not made of his available strength through more than half of each ascent of the body. And it may be imagined that by economising his resources, and distributing his force in a different manner, as by lifting himself each time to only half the height, he might double the effect. I doubt it; but allowing it, he could not thus do more work than would raise him to a height of eighty feet; and I know that swarming up a pole or rope forty feet (a mode of progression in which, though the arms do the chief work, the legs contribute to the effect) is work enough for most men whose limbs are well strung, and is more than one man in twenty will accomplish without practice.

No one, I conceive, will imagine that a better hold can be got of the air than of a rope or pole; and in all attempts to fly, the weight of the wings and other apparatus must be taken into account. I do not suppose a good grip could be taken of the atmosphere with a propelling surface and mechanism weighing less than ten pounds. An addition of such weight will of course diminish proportionally the height which could be attained.[1] So that thus we get a notion of what is the limit to a man's power of elevating himself into the air by his arms.[2] It is

[1] If an ordinary man, weighing about 150 lbs., can raise himself to a height of 80 feet, and if his available force is supposed to remain the same under the different resistances, he would be able to raise 160 lbs. to a height $\frac{150 \times 80}{160} = 75$ feet.

[2] It is not unlikely that some of the accidents recorded as terminating attempts to fly, have arisen from men doing thus much, and then becoming quite exhausted, and falling from inability to continue the exertion. It is worthy of note, too, that most of these unlucky wights started their flight from tops of high towers, instead of from boats in the middle of lakes or

scarcely necessary to consider farther in this place his capacity for flight, in which this supposed attempt to soar upwards would have to be in part converted into a forward motion, in which the resistance of the air would have to be in part combated, in part trusted to for maintaining the body at the height acquired. If a man would be unable to rise beyond eighty or a hundred feet without fatigue, his flying would be of little use.

Now, however, with respect to a man's legs the case is very different. It is impossible to consider the human figure without being struck by the enormous mass of muscles collected about the lower half of the body. Almost the whole muscular system is concentrated into the part below the hips;[1] the symmetry and gradual tapering form of the legs of man are expressive of power, as they are highly gifted with it, and fitted for its display. There are but few among the mammals that have anything like such a concentration of power in proportion to their weight in any one part. Moles, bats, and some monkeys it is true have their fore, and kangaroos, their hinder limbs favoured, as it were, at the expense of their other muscles. But very few of them, except perhaps the latter of those just mentioned and a few others, can boast such capacity for vigour in any one part, as can man in the exquisite taper of line from the muscle-loaded hip and thigh to the light arches of heel and toe. It will be said perhaps that many quadrupeds have a much greater vigour of fibre than we have—as I have allowed for the birds. The answer is that, firstly, no mammal shows a degree of muscular activity comparable to that displayed by birds of perpetual flight; secondly, that there is no reason for supposing that there must be any great difference of muscular tone between man and other mammals, in favour of the latter. What do we, sauntering lazily on lawns and carpets, or

the sea, which, of course, every reasonable man would do in such an experiment.

[1] In the human body the law of polarization—one of the chief laws of the harmony of nature and of organic development especially—is worked out in the highest visible perfection. The polarity expressed in the physiological fact specially spoken of here, is that between two of our lives, the volitive and motive, the mental and the muscular, the brain and the limbs.

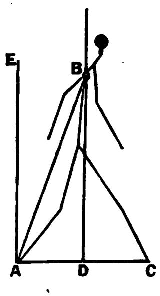
poring over some sedentary toil for hours of murderous fatigue, know of the capabilities of human muscles? Yet anyone who will remember the feats he may have seen performed by exhibiting athletes, may be reminded that there are faculties dormant in us of which the old Greeks knew the value, and which they were careful to educate. But, it may be said, we are not all to be exhibiting athletes, mere brainless pieces of muscular mechanism, such as these poor animal incarnations of strength and agility. Certainly we are not to be mere muscular mechanisms, but were the men who worked at the Parthenon and played at the Olympian games mere brainless animals? And, which is a greater question still, are those poor clowns who may be seen performing prodigies of might, even in the streets, for their daily bread—are these fellows the mere animals we take them for? have they not capabilities and susceptibilities, which if they were but brought out and directed would make them just as good men as you, reader, without the loss of one grain of their admirable animality? Besides, for a fact, at our schools and universities, are the best scholars the least vigorous at manly games, or the most athletic men the greatest dunces? is it not rather notoriously the reverse? I say then there is every reason to believe that man is capable of putting forth far greater strength with his limbs—especially with his lower limbs—than he generally believes; and that in not attempting to develope our muscular powers to an exalted degree, we are neglecting a most valuable part of education.

But we shall be wiser some day. The question for the present shall be, what can we do with our legs, such as we find them? In considering the power of our arms and their suitability for flight, I have put the question in a form which will serve us equally well for enquiring whether our legs can serve us in this matter. Does the weakness of these latter limbs itself at once set such a limit to our hopes of making use of them, as to discourage or forbid any attempt to tax them for this purpose? I think not, and I shall briefly show the reason, by referring their powers to the same test as that by which we tried the arms. Now, it would seem a waste of words to argue that a man can raise himself by his legs. Without going up a ladder (which is in fact a flight in which support is taken from the run-

dles instead of from the air) no one can advance a step on level ground without lifting his entire weight. Each step (starting from the erect position) commences by a fall forwards, which is arrested by the advancing foot as it reaches the ground. Now, if there is a fall, it must be followed by an equal rise, which is effected by the leg that is left behind, which pushes his body forwards and upwards, till the centre of gravity recovers its former height. The body is thus raised in walking chiefly by the muscles of the calf, extending the foot and opening the angle between the instep and the shin. The leg that did this part of the work and was left behind, is then lifted by itself and brought forward to receive the next fall in its turn. The longer the step taken, the greater the height through which the walker falls, and the greater therefore the height through which he must raise himself. I shall not overrate the height through which the centre of gravity of the body falls and is lifted again, if I assume it at three inches for every complete step of a yard.[1]

[1] That this is not assuming too much fall and rise for each step, will, I think, be evident from the following rough considerations. Suppose our man's centre of gravity to be, when he is erect, at a height of four feet from the ground, near which it will be in a man about 5 feet 9 inches high. Let A C (fig. 1) represent his full step = 3 feet, A D, the half of it = 1 foot 6 inches. D B, the perpendicular height of his centre of gravity above the ground at the middle of the step. Let A B be the distance of his centre of gravity from the point of support at his foot. Let us suppose A B to be equal to A E, the height of his centre of gravity from the ground, when he is erect. It is evident that A B cannot be greater than A E, for the bending of the joints brings B nearer to the feet than it is in the upright position. So that A B is, in fact, less than A E. And the less A B is, the less, of necessity must, B D be; and therefore the greater will be the difference between A E and B D, which excess of A E gives us the measure of the fall. But we will assume A B = A E, that we may not exaggerate the fall. Now A D B is a right angle, therefore $AB^2 = AD^2 + BD^2$, i.e. $4^2 = 1{\cdot}5^2 + BD^2$, or $BD^2 = 16 - 2{\cdot}25 = 13{\cdot}75 \therefore BD = \sqrt{13{\cdot}75} = 3{\cdot}708$ (feet) $\therefore AE - BD = 4 - 3{\cdot}708 = {\cdot}292$ feet $= 3{\cdot}504$ inches. Nearly $3\frac{1}{2}$ inches; and this is less than the correct result. And I think that if the reader will try the experiment by stepping a yard

Fig. 1.



If this be so, in walking a mile a man will have lifted himself through $.3 \times 1760$ inches $= 146{\cdot}6$ yards; so that his mile's work may be represented as equivalent, so far as his legs are concerned, to a flight directly upwards to a height of about 146 yards. Now, if we reduce his height proportionally to the additional weight due to the wings he must be carrying if he flies; taking the same weights we assumed for the ease of the arms (viz. 150 lbs. of man, and 10 lbs. of wing), it becomes $\frac{150 \times 146}{160}$ $=136{\cdot}8$ yards. Now every sound man ought to be ready to walk 30 miles for a pastime any day. In walking 30 miles he would, according to our calculation, have done work equal to lifting himself and his wings to a height of $30 \times 136{\cdot}8 = 4104$ yards (at least $2\frac{1}{3}$ miles) directly upwards. In confirmation of this inference may be taken the fact that the miners in the lowest levels in the mines in Cornwall, after going down the ladders, which is three-quarters of an hour of work, certainly not much less fatiguing than an equal length of time spent in going up, and after many hours' labour in the mine, do actually lift themselves and their tools to the surface by travelling up the ladders, in which toil they spend hours; preferring this course to what they consider the dangerous expedient of being hoisted to the 'grass' in the kibbles. So much for the capabilities of our legs to carry out Bishop Wilkins' device of 'walking or climbing up into the air, by the legs being thrust out and drawn in again one after the other, so as each leg should move both wings.' If the reader should

by the side of a wall, and measuring the height of the pit of his stomach from the ground at the mid position of the step and when he is upright, he will find that this is pretty near the truth, so that I might at least treble the amount of work shown to be done on my assumption, without any exaggeration. In ordinary walking these actions do not take place precisely in the order here represented, though they actually occur in deliberate striding. In progression at the ordinary foot-pace, lifting of the body by the after leg is simultaneous with the fall forward. The end attained by this adjustment is a compensation of one movement by the other, so as to keep the head travelling in nearly a horizontal line, and to free it from the continuous jerking motion to which it would otherwise be subjected. But exactly the same amount of work is done in making an equal advance however the steps may be made.

prefer to strike out with both legs at once, as is commonly done in swimming, let him stand on his hearth-rug, put his feet together, and spring up and down either by simply extending his feet, or by calling his knee-joints into play without even taking his toes from the ground, and I think he will (even with a weight in his hand) satisfy himself, if he is at all strong on his legs, that they are equal to the work I am suggesting for him.

The enquiry now arises—Can the power thus available be applied to the air without such loss as to make it useless in practice? This I do not undertake to demonstrate, but shall leave the question to the advocates of mechanical flying: in attempting to solve this problem, however, provision must be made, that, in case of an accident, the flyer shall not at once fall headlong. Again, if wings are to be the instruments of motion, and they are the simplest and most effective that can be devised, it must be remembered that their action is alternate. They must, of course, shut up completely during the up stroke, so as to offer no considerable resistance to the air in that direction. Some contrivance therefore will be necessary to maintain the height acquired by one stroke during the interval that elapses before the next descent of the wings, unless their movements are so rapid that their action shall become equivalent to a uniform upward force. Some form of kite or parachute will be necessary to effect this end.

What chance have we now that our wings will do justice to our legs? they must take hold of the air, as our feet do of the rundles of the ladder. What we want then is to get them to receive a resistance from the air at least equal to the weight to be lifted. This must be obtained from them before upward motion can commence. Now, for sake of simplicity, we will suppose our wings to be square and perfectly flat, and to move directly up and down, so that each point on their surface shall move with the same velocity. This will not be the case, for each point in them will describe an arc of a circle about the point which will be near the shoulder, so that the outer points travelling in larger circles will move faster than those near the body. We shall assume the whole wing to move in the direction, and with the velocity of its centre, and parallel to itself through the distance traversed by the centre.

So we will begin by fixing the size of our wing: let it be seven feet square. Then we have $s=7^2=49$, our equation, then, becomes $80 = 005 \times 49v^2$, or $v^2 = \frac{80}{\cdot 005 \times 49} = 326\cdot 53 \therefore v = \sqrt{326\cdot 53} = 18\cdot 07$. Thus our wings being each seven feet square must be moving with such a velocity that if the motion continued for a second, they would traverse eighteen feet,—before their resistance would neutralise the weight of the system—before it could commence to move. Any additional power over and above this that could be exerted upon them, would be expended in lifting the body. During the whole time of flight this velocity, or its equivalent, would be kept up; but their downward movements alternate with upward jerks, which are at least useless, and must indeed take off something from the available force, however much their resistance in that direction may be diminished by their form. The velocity of the wings in their downward motion must therefore be increased, to make up for this abstraction. If we suppose that the flyer allows as much time to elapse between each impulse as is occupied in making the stroke, the force expended in each extension of the leg must be doubled, so as to double the resistance of the wing. To maintain the equilibrium, then, we must have $v^2 = \frac{160}{\cdot 005 \times 49} = 653\cdot 06 \therefore v = \sqrt{653\cdot 06} = 25\cdot 55$. So that to remain poised in the air, neither rising nor falling, the wings must be kept vibrating with such a velocity that, in their downward stroke, they move through $25\frac{1}{2}$ feet in a second. Now, according to our ground, that a man in walking a yard must raise himself an inch, in walking at the rate of four miles an hour, he will do work at least equal to raising himself 1760 inches in fifteen minutes, i.e., 117·3 inches in a minute, or 2 inches in a second nearly. We may, without overtaxing the man, suppose him capable of making ten complete beats of the wing in a minute;[1] then in half of this minute he will put out

[1] He will work, of course, only with the down strokes with his legs; so as to make the strong extensor muscles bring the wing down, and stretch a vulcanised india-rubber spring, which will draw the wing up again at the end of the stroke, thus leaving to the flexors only their natural office of

all the strength he can afford; that is to say, he will do in 60 seconds the whole labour of ten strokes, or he takes 6 seconds for each down stroke. But he can supply the requisite force at the rate of (160 lbs. raised) 2 inches in a second, or 1 foot in 6 seconds. This will be equivalent to raising his body a foot in 6 seconds, which, if the reader will try, he will not find any distressing work. Each down stroke, then, will be a foot in length, and will occupy 6 seconds. Now, I want to deduce from this the *length* of the wing, or rather the distance at which its centre must be from the joint. The wings will have to move for 6 seconds in one direction, at the rate of $25\frac{1}{2}$ feet in a second, and will have to traverse a space in each stroke of $6 \times 25\frac{1}{2}$ feet. The foot from which the force is applied, moves through 2 inches in a second, the wing has to move through 306 inches in the same time. Let us suppose the force transferred by a link from the foot to a point of the wing, at a distance of one foot from the joint. This joint of the wing-arm will move through 2 inches in a second, or more correctly, through a circular arc of 12 inches radius, and of which 2 inches is the cord; and the length of arc moved through by any joint is in proportion to its distance from the joint. Representing the distance of the centre of the wing from the point as x, we have $\frac{x}{12} = \frac{306}{2} \therefore x = 1836$ inches $= 153$ feet.

lifting the leg. I have taken ten beats in a minute as a round number, and less likely to be fatiguing than a quicker and shorter stroke.

CHAPTER III.

THE IMPOSSIBILITY OF PROPELLING BALLOONS, AND THE FIRST DIFFICULTY IN AERIAL NAVIGATION.

I NOW come to the second case of aerial propulsion, viz. that in which the weight of the body to be moved is neutralised by the support of a buoyant gas. It would be very natural to suppose, at the first glance, that the vast assistance afforded by the discovery of this application cleared the way at once to a realisation of our hopes of flight, and left us nothing to do but to flap our wings and go ahead at any pace required. There is no doubt too, that many of those who first witnessed the ascent of the balloon conceived that the empire of the airs was henceforth our own. Blanchard, indeed, who had been at work with his wings for years, hailed the invention as the solution of the problem he had undertaken. He was, however, undeceived, and found that the difficulty which had been vanquished had risen up in another form in which it defied his efforts as effectually as before. It was a beautiful but disappointing instance of the compensations which prevail throughout nature, keeping things and events upon the groove of law even when they seem most inclined to start from the old routine. Gravity was beaten, but resistance of the air rose up and laughed to scorn the exultation of the eager world. It was found impossible to propel the balloon. A sphere of hydrogen, large enough to support a man, presented so extensive a surface that the resistance of the air to its passage through it, at any speed worth obtaining, would be at least equal to the weight that it neutralised. This fact which was soon ascertained by the inventors, and then predicted by the men of science, discouraged the early schemers in their attempt to im-

prove the evident advantage gained over nature by the appplication of light gas. And the same drawback has caused the balloon to be looked upon ever since by all sober people, except a few who have enquired for themselves, as nothing but a mere toy—and a mere toy the balloon and its gas have remained.

But hydrogen has a better destiny to fulfil. This I shall endeavour to prove; but before proceeding to enquire how the gas can be made to serve us in our purpose of navigating the air, I must state why, if I did not fancy I saw the road clear to full success in flight by the aid of hydrogen, why,—even if the obstacles to the two methods were apparently alike—I should select the resistance of the air for an opponent in preference to gravity, why I should try to improve upon the balloon, before I essayed to fly without its aid.

In the first place many ingenious men have devoted a great deal of time to actual endeavours to perfect mechanical flying, and hence failed; while very few reasonable experiments have been made towards the propulsion of gas vessels. Secondly, I might have some hopes of diminishing or eluding the pressure of the air; none of cheating gravity. Thirdly, if I was aloft on my wings alone, and broke one of them, my neck would be likely to be broken too; in the second case, an accident to my propelling mechanism would only deprive me of my speed, not of my life. Fourthly, as corks are sometimes useful in learning to swim, so, even if mechanical flying were the ultimate aim, previous practice with gas floats might perfect us in exercise, and in the use of mechanism, in which we could not acquire skill without such aid at first. Fifthly, I find a difficulty in believing that the marvellous lightness of hydrogen,—that thing of such singular tenuity, that, though it more obstinately resists compression than does any other known gas[1], is of a nothingness almost as utter as a vacuum—is not specially intended to do some service to man—to deliver us in some degree from the bondage of gravity. Sixthly when I reflect upon the enormous

[1] Faraday, in his experiments on the liquefaction of gases, found it impossible, with the most perfect apparatus, to keep hydrogen under a pressure of more than twenty-seven atmospheres.

stores of it which are piled about the earth—when I consider that there is enough hydrogen in the ocean to lift[1] * * * * * *

I cannot doubt that the work which this mighty agent has to accomplish is one of blessing to the human family—and I know no greater boon that it can confer on us than that of drawing us closer together in amity by lifting us over the barriers that hinder our intercourse.

Now what is the reason that the utility of hydrogen is still latent? that neither embryo balloon has ever been raised against the air, nor organic gas-vessel propelled? The answer is brief.

The balloon has been moved by oars, just enough to make it rise or fall, or to divert its course in still air slowly and laboriously to a given point. To propel it is simply impossible. And as to vessels of more likely form than the heavy sphere. Firstly, it is probable that no man who knows how to pull an oar in a boat with any effect has ever tried his hand at it. I never heard that a Thames waterman, or a man who had pulled in a race up the long reach at Cambridge, had ever had his foot against a stretcher under a bag of gas. Most of the attempts at balloon pulling have been made by ingenious citizens of Paris,

[1] The seas and oceans are calculated to contain 146,500,000 cubic miles (English) of salt water. Of this material about $3\frac{3}{4}$ per cent. consists of salt and other substances kept in solution. The rest is pure water consisting of oxygen and hydrogen, in the proportion by weight of 8 to 1. One ninth, therefore, of all this mass is hydrogen, and each gallon of water in the sea contains 1 lb. and 500 grs. avoirdupois, of hydrogen. Now one pound of hydrogen occupies 327,100 cubic inches, while an equal bulk of common air is weighing fifteen pounds. So that every pound of hydrogen represents a lifting power equal to the difference of those two weights, viz., fourteen pounds, and every gallon of water a lifting power of fifteen pounds. Not a power, per pound and gallon, to be measured by such weight lifted a foot high, as we speak of steam power and horse power, nor a force which we can fully appreciate by considering it merely as a statical pressure, but an accelerating force, uncompromising, like gravity, and ready to hurl any obstacle less than that of the weight which can resist it, to an infinite height, at least to the very bounds of our atmosphere, if such there be to stop it.

This blank space was not filled up by the author, and we leave the reader to calculate the lifting powers of all the hydrogen in the ocean. —ED.

who cannot be suspected of being likely to do much work in an eight-oar. Secondly, if the best crew that ever bent their backs to stroke, were to lay out their best strength upon oars, sweeps, or wings in the boat of the best shaped air-craft that has yet (so far as I can learn) been designed, they would do little or nothing towards getting any way on the vessel. And this partly from want of sufficient power, but chiefly from an inevitable misdirection by the machine itself of any force that they might apply to it. Thirdly, competition among intrepid inventors and aeronauts, and want of co-operation among those who might have aided their experiments, has checked the early life of the art and prevented any vigorous efforts being made to develop it. The balloon has become a means of making a livelihood, which held out to needy men generally innocent of science, a prospect of acquiring a competency, and perhaps wealth, with the addition of notoriety. While then they have been racing with each other up to the clouds for mammon or a maintenance, it was not likely that they could stop to consider whether it were possible to travel together upon a level course. What again could be done by isolated contrivers? One describes his device in a journal or writes a pamphlet, another criticises his plan, picks out some absurdity, and proposes a rival crotchet of his own, with which some one else finds fault in turn. One burdens himself and his scheme with letters patent. Another pompously declares he has solved the great problem, but will not make revelation thereof till he is well paid. And the men of capital, who, each by himself, might be able to do but little to favour the growth of an useful art, however well disposed to do so, are either unwilling to unite their means, except for the purpose of increasing them, or have been discouraged by the repeated failure of former individual schemes.

Aerial navigation is a social problem, promising by its solution to contribute more than any other physical means to bring all mankind together, and realise the golden age, when 'there was no more sea.' And so men are to unite in their endeavours to perfect the art, and not to leave it to grow by competition, lest the age of its accomplishment be indefinitely postponed, or lest every scene of the vision of the world be fulfilled—

there rained a ghastly dew
From the nations' airy navies grappling in the central blue—

which God forbid.[1] The French at first saw this, and hailed the balloon as a gift to their nation at least, which they were to do their best in concert to improve. The public experiments with Montgolfier's invention[2] were made at the expense of the Academie des Sciences, and when a subscription was opened to build the first hydrogen balloon for Charles and Robert, people rushed to pour their donations into the fund. In London too, the first experiment on a large scale, that of Luccaroli, was carried out by subscription, and even in modern money-seeking days, if a ballooner meets with an accident and loses his property, the generous people often raise a fund to set him up again. It is to be hoped the same brotherly spirit may yet unite us in the endeavour to elevate a childish pastime into the manliest and most humanising of arts.

But to return to propulsion. I have said that to propel the balloon is simply impossible. This has long been apparent to mechanical minds that did not happen to be enthusiastic about aeronautics, and has been pointed out over and over again,[3] and the difficulty has been supposed by many objectors to be an insurmountable barrier to any attempts to direct gas-vessels of any form. That which is an impossibility for the balloon, is still a serious difficulty for gas-vessels of a more reasonable shape. Many schemers have gone inventing on in defiance of the obstacle; others have proposed to elude it by methods theoretically appropriate, but very difficult of effectual execution. I will first state the case as respects the balloon; and then show that it is

[1] There will be this special unfitness for war in all air-craft, that every missile discharged, or bomb let fall, would suddenly send the vessel rushing to the skies, by diminishing the weight borne by the gas, if it did not also capsize it, by disturbing the horizontal equilibrium of the system.

[2] St. Fond. 'Exp. Aer.' v. i. pp. 8, 32.

[3] See 'Mech. Mag.' vol. xxv. pp. 158, 308, 408; vol. xxvi. p. 168; vol. xxxi. p. 292. The tendency of the balloon to spin round its vertical axis, has been represented as a great obstacle to its propulsion. This would be a trivial impediment, that would easily be overcome if the air would allow the balloon to be propelled at all.

equally applicable to most of the improvements upon it that have been contrived.

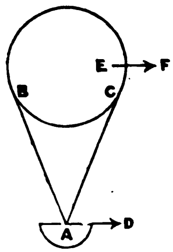
The impossibility of forcing a balloon to move at a very rapid rate in a horizontal direction [1] arises primarily from the form of the sphere, which opposes a resistance to the air not very much less than that of a flat surface – a resistance, therefore, which would require an enormous force to overcome it, a force which it would be vain to endeavour to carry.[2] But this is not of

[1] I specially mention the horizontal direction, because a great speed is frequently given to a balloon mounting directly upwards, by suddenly relieving it of weight. For instances of this I must refer my readers to Monck Mason's 'Aeronautica,' and to the account of the fatal parachute experiment of Mr. Cocking, which appeared in the journals of the day, and may be found in 'Mech. Mag.' v. xxvii. pp. 259–261. It is very possible that the springing up above a thousand feet in a moment, on the casting out of 56 lbs. of ballast, in the first case, and the shooting upwards with the velocity of a skyrocket in the second, on the detachment of a weight of 393 lbs., may be a somewhat exaggerated statement, but the velocity must have been great to have so vividly impressed the minds of the narrators. In such cases the balloons are, of course, impelled by a uniform accelerating force equal to the weight thrown off (supposing them floating at equilibrium before). But I doubt whether a sudden addition of an equal weight to the load of the balloon would cause it to fall with the same velocity. In the first place the pressure of the air on the loose yielding surface of the lower part of the falling balloon would tend to cave it in, and so, increasing its resistance to the air, give it a tendency to act as a parachute. On the other hand, in the sudden ascent, the upward pressure of the gas on the crown of the envelope keeps it tense and convex, while the lower part is free to adapt itself to the new condition of diminished pressure, which must tend to elongate it downwards. Besides—and this must vastly facilitate speed—the balloon as it rises is continually entering a medium offering less resistance than that which it is quitting, and its wake is occupied by a denser air, which by its expansion can fill the vacuum which a body moving rapidly in a fluid always tends to leave in its rear. The very gas too in the balloon, as it expands under the diminished pressure, rushes out of the neck, and must help, like an actual tail (which is an essential requisite to speed in water or air), to fill the space left behind the advancing body. It does not therefore follow that a uniform force equal to a pressure of a certain number of pounds would, if properly applied to a balloon, propel it in a horizontal direction with a velocity equal to that with which the discharge of as many pounds of ballast will cause it to rush upwards.

[2] For a calculation of the size of the smallest balloon that could lift a

course the difficulty which is common to the balloon and to vessels of other forms. This other obstacle to success, which is secondary in the balloon, but which becomes of fundamental importance in improved air-craft, which may be supposed to have surmounted or lessened the former inconvenience, is the difficulty of so applying any force exerted in the car of a balloon, or boat of a proper vessel, as that it shall tend to urge the gas-envelope in the desired horizontal direction. The nature of the difficulty will be at once understood from the annexed diagrams, and by the following considerations. Let A B, A C, fig. 2, represent opposite cords by which a car is suspended to a balloon. Let E F represent the horizontal line in which it is hoped to propel the balloon, A D the direction in which the propulsive force acts on the car. The angle which the direction of A D makes with the vertical axis of the car, will, of course, be determined by the position in which the propelling mechanism is fixed to the car. Since a horizontal motion is required, the propellers will, of course, be adjusted to exert a force acting horizontally, i. e. in a direction at right angles to the vertical axis of the car. If a feeble force be applied, only a slight motion will be given to the car, and the force being transferred by cords to the balloon, will impress on it a similar slight motion. Now, the resistance of the air to bodies passing through it is proportional to their diameters and to the squares of their velocities. If the velocity is very small, the actual resistance on each square foot of surface will be very small, and, therefore, the number of square feet of sectional area or of surface will not make very great difference in the quantity of resistance encountered. If then both the car and the balloon have, as we have supposed, but a slight motion, the resistances they both meet with will be but slight, and therefore, though there is great difference in their sizes, there cannot be much difference between the amounts of retardation they respec-

Fig. 2.

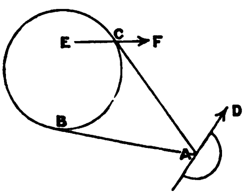


crew sufficient to propel at a certain speed, and of the number of men necessary for the work, I beg to refer the reader to Mr. Mason's 'Aeronautica,' p. 322.

tively meet with from the air. The balloon therefore will keep up, or nearly so, with the car, and the weight of the car or its pull upon the balloon will be sustained equally by A B and A C, and the motion will thus continue. A very slow motion then is possible to be produced in this manner, and just thus much has been accomplished.

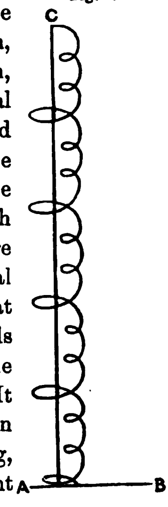
But, with regard to rapid motion, the case is very different. This will be best illustrated by taking an extreme case. Let us suppose the rising power of the balloon to be exactly balanced by the weight of the car, and let us suppose the car to be urged in the direction of its length by a great force, and let this force be sufficient to drive it up into the air and to carry it along in any direction, without the assistance of the balloon, at a velocity greater than that at which the balloon could rise if freed from the car—a condition apparently very promising of success. Let us suppose that the whole system is already in motion through the air at the greatest speed at which the balloon can be urged. Now, what takes place? The resistance of the air being proportional to the square of the velocity multiplied by the square of the diameter of the moving body, if the velocity becomes considerable, the resistance becomes very great, and in this case the difference in size of the bodies (as measured by the diameter perpendicular to the line of motion) makes a great difference in the resistance they meet with. Let us suppose that the horizontal velocity of the whole system is such that the resistance is one pound on each square foot of sectional area, and that there are 700 such square feet for the balloon, and 7 for the car (which there will be if the former is about 30, and the latter, 3 feet in diameter, both supposed spherical): there will then be a resistance of 700 lbs. to the onward motion of the balloon, and only 7 lbs. to retard the car. The result of this is, of course, that the balloon lags behind the car, and the system assumes the position represented in fig. 3. This tendency will be first exerted in throwing a greater strain on the hinder cord A B, which will now transmit the pull from the car to

Fig. 3.



the balloon. It is quite evident that the cord A C cannot be of the slightest assistance in drawing the balloon forward. The point B will be drawn downwards and forwards, and the point C being relieved from the strain will rise, so as to keep the cord A C tight, by throwing on it a share of the weight of the car. The consequence of this is that the axis of the car, which was originally vertical, is now no longer so, and that the propelling force which is acting at right angles to this, and which was originally horizontal, becomes now inclined at an angle to the horizontal line E F. Farther, it is quite evident that as this continues, the direction of the force A D must become less and less horizontal, till it becomes actually vertical, and the car has risen to the level of the horizontal diameter of the balloon. The propelling force now bears the whole weight of the car, and the balloon rises as if it were free, but by our hypothesis the car can rise faster; it therefore outstrips the balloon in its ascent—just as it did in its first horizontal motion. A similar succession of changes must ensue, till the car would come directly over the balloon, and would be driving away in a retrograde direction with passengers' heads downwards. In short, the car would now be revolving round the balloon, exactly as the moon travels round the earth, without making the least progress in a horizontal course, while the whole system would be carried up to the zenith by the ascending force of the balloon. The gas-globe would mount, as the earth marches onward in its course, hurrying with it the swinging whirling moon, or in a far more complicated course, which would be symmetrical about a vertical straight line, intersecting it at regular intervals, and whose loops and bends would depend partly on the rising power of the gas, partly on the propelling force of the car. It would travel in some such path as that traced in fig. 4, in which A represents the place of starting, B the point required to be reached, C the point actually attained.

Fig. 4.



If, however, the car were driven by a more moderate force,

sufficient, for instance, to propel the balloon itself, if applied directly to it through its centre in a horizontal line, with a considerable speed, of course this revolution could not ensue. The balloon would lag behind the car, and the car would rise, just as is represented in fig. 4, to a position in which the contending forces would be in equilibrium. The direction of the propelling force would remain constantly at such an angle with the horizon, that only a certain portion of it would be virtually exerted in the forward line, the rest of it being uselessly employed in lifting the car upwards. The consequence of this would be, that the balloon being relieved of a portion of its load would rise, and the course of the whole system would be in a straight line slanting to the sky, of which the angle would be determined by the power of the propeller. There would be a certain limit beyond which any additional force exerted in the car would not only not be available in a horizontal sense, but would actually diminish the forward movement; till at last the horizontal progress became nothing, and the path became such an upward curve as was just now described approaching more or less nearly to a vertical straight line.

Now in the case of the balloon, if a force sufficient to propel the sphere could be carried in the car, this difficulty might be overcome by shifting the mechanism that applied the power to the air so as to maintain its action constantly in a horizontal line. In this case, the greater the power the higher the car would rise with respect to the balloon, so that the line between the centres of the two bodies would become more inclined to the perpendicular; the limiting position beyond which it could not get if the force were infinitely great, being the horizontal. In this case, with an infinite horizontal force, the car would be dragging the balloon directly after it, the centres of the two bodies being exactly on the same level.

But, as has been said, the resistance of the air to the motion of a sphere is so great that it is not worth while to make any contrivances for the purpose of driving or drawing it along.

So much for the balloon. I have entered at some length into the explanation of this obstacle, because it is fully as great an impediment to the progress of air-craft of reasonable shapes, as it

is to the propulsion of the old globe. Let now the sphere be elongated into an egg, and let the car be suspended by cords radiating all round from the mid zone of the gas-vessel as in fig. 5. Now it is evident that just the same conditions attend this arrangement. As soon as the longitudinal force acts on the car in the direction of G, D, the cord must slacken and A B become tightened by the draft which it transmits to the tail of the eggoon. The latter end, therefore, of the gas vessel is drawn down and the former end tilted up. So that the system must assume a position similar to that represented in fig. 6. Now it will be observed that this second state of things is even worse for the eggoon, or for any other elongated form, than it is for the balloon. For in the case of the latter, which is symmetrical in all dimensions, the resistance of the air to its progress is equal at a given speed, whichever side may be presented foremost. But in the case of fish- egg- or cylinder-shaped vessels, which are of course planted at starting in the position of least resistance, their horizontal set cannot be altered without increasing the resistance they encounter. And the more fitted the form might be to elude resistance when in its proper bearing, the greater would be the opposition it would create to its own movement as soon as this might commence: for with a given amount of cubic contents, the more the sectional area in one dimension is diminished, the more it must be increased in the others, and the more therefore must it provoke resistance, when any other side but the intended ends is employed to face the opposing air.

Fig. 5.

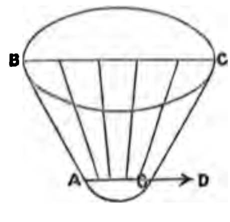
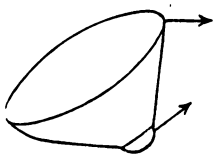


Fig. 6.



I have spoken here of an air-craft in which the boat is suspended by flexible cords from an oval gas envelope, because this is the construction most usually proposed and adopted. It was, for instance, the arrangement contemplated by Sir George Cayley in his design for a navigable aerial vessel as represented in his

published sketches.[1] The same method appears, too, to have been adopted by M. de Lennox for his ship the 'Eagle' intended to have been aerial,[2] and it was the form of Mr. Bell's apparatus, in which[3] he made two ascents in London in the summer of 1850. I quote these three instances as being—the first, the contrivance of the most scientific, of probably the oldest, and certainly the most persevering advocate for the traffic of the air; the second, the project that at its time (1835) created more talk in Paris and in London than ever was the lot of any other supposed improvement in the balloon; the third the latest actual experiment of this kind exhibited to the English people.

I have taken no notice in these considerations of the part of the apparatus represented in the case of the balloon, by the hoops usually placed between it and the car, because the presence of this appliance does not at all alter the dynamical conditions of the system, whether the force be made to act from it, or still from the car. This part of the apparatus serves no useful purpose, except that of relieving the edges of the car from the outward strain of the diverging cords that tend to wrench it open by stretching it in all directions.

It should, however, be mentioned that some inventors, amongst others M. Monge,[4] have supposed that by applying the force at a point between the gas-vessel and boat, for instance, at the centre of gravity of the system, this twirling tendency would be obviated. This, however, is a fallacy. The force in such a case will tend to twist both boat and gas-vessel in opposite directions, to throw the head of the former down and the latter up; in exactly the same way as has been already explained, the system would assume the form represented in fig. 3, unless the resistance of the air to the boat were nothing. However, many propounders of schemes for propelling gas-vessels have proposed to connect their boat into one rigid system with their eggoon or other gas bag, by means of a stiff frame-work. As instances of this may be men-

[1] 'Phil. Mag.' vol. xlvii. pp. 83 (1816, Feb. No. 214), 329; and 'Mech. Mag.' vol. xxvi. p. 424 (1837, March 4, No. 708).

[2] 'Mech. Mag.' vol. xxiii. p. 289 (1835, July 18, No. 623).

[3] 'Ill. News,' July 27, 1850.

[4] Monge, 'Études,' p. 132.

tioned the project of M. le Baron Scott,[1] (1789), that of M. Génet in America[2] (1825), and Mr. Partridge's imaginary 'Pneumadromon'[3] (1843). It is evident, however, that this arrangement does not obviate the difficulty of propelling from the boat; unless the boat is so enclosed in the gas-vessel as to distribute the resistance of the air to the envelope above and below the level at which the power is applied. Scott's is the only one of those here mentioned, or that I have met with, in which this is contrived; and this is one of the earliest, and in many points one of the cleverest, of the schemes recorded. If this condition is applied in a practicable form it will meet this difficulty, but if the boat be fixed to the framework below the gas-vessel, the only difference between this case and that of flexible suspension is, that no motion of the man-vessel can take place before the gas-vessel begins to heel. The tilting effect must commence instantly; the machine being in fact acted on by a system of two forces equal, parallel, and opposite in direction to each other, which tend to twist it round, and which are called by mathematicians 'a Couple.' If, on the contrary, the boat be close up to the gas-vessel or, as in Scott's scheme, within it, for the purpose of preventing the twisting effect, another fatal error is introduced. The centre of gravity of the system is brought so high up, so little below the centre of buoyancy, that the stability of the system in a horizontal position is reduced to the lowest degree; the slighest force tending to throw either end up or down, will cause the whole to vibrate like a balance beam without any pans arranged for the greatest sensitiveness. But returning to the former case, the two forces of the couple acting on the gas-vessel and boat placed below it are, the resistance of the air to the head of the former, and the propulsive force acting on the latter from its stern.[4]

[1] Scott's 'Aerost. Dirig.' p. 56.

[2] Delcourt, 'Manuel,' p. 143, pl. 7, quoting 'Mémoire sur les Forces ascendantes des Fluides,' par M. E. C. Génet.

[3] 'Mech. Mag.' No. 1032, May 20, 1843, p. 396.

[4] A good instance of this twisting movement may be seen in the actions of a swan, when trying to swim in a pompous style. The bird brings its foot well forward and upward to ensure a vigorous stroke, and in thrusting it

If any other force be acting on the air-craft, it will of course produce, independently of, and simultaneously with the twisting effect, the amount of locomotion due to it. Such other force may be supplied by the lifting power of the gas, which will be set free by as much of the force from the boat as is resolved directly downwards. Now, if the driving power be infinite, it, combined with the upward force of the gas, will produce a twirling ascent as in the case of the balloon. But if it be finite, it will confer an upward sloping course. For the twisting motion will be stopped at a certain stage, by a new 'couple' acting in the opposite direction to the former, and in equilibrium with it, of which the two forces are, the lifting power of the hydrogen, and the weight of the boat. The degree of inclination given to the system by the first 'couple,' before the twisting effect is checked by the second (which will be continually increasing in power as the inclination increases) will be determined by the strength of the propelling force in the boat. So far the forces have only operated to determine the position which the system will assume, and this position is one of statical equilibrium, to which the system will return if displaced from it. But when this state of things is attained, the conditions assume a different form. The lifting power of the hydrogen is relieved from a part of the weight of the boat, which now goes to balance that part of the propelling force which is resolved in a downward direction; so the gas-vessel begins to mount. Meantime, the rest of the propelling force acting on the car is resolved in a horizontal direction. There are now two forces acting on the car; the upward pull of the gas, and the residue of onward force from the propeller. Their resultant will be in the diagonal of a parallelogram, whose sides are vertical and horizontal, and are proportional in length to these two forces. This line will be an upward slant, more and more nearly approaching the vertical, as the force of the propeller is greater;

back, obtains the first result in lifting its breast out of water, above its usual water line, while its stern sinks to an equal extent. This is caused by the first part of the circular arc, described by the bird's foot, being in a downward direction, so that the force exerted is an upward one on the fore part of its body. Self-satisfied creatures are apt to waste their power in this way.

and will be exactly vertical if this force be exactly equal to the weight of the boat. If it be greater, the boat will outstrip the gas-vessel in the race upwards, and will be compelled to turn round it, to commence the same path again.

I said before that, though many inventors had contented themselves with ignoring this cardinal difficulty,[1] others had endeavoured manfully to surmount it. I proceed to notice some of the methods by which it has been proposed to accomplish this. The principle applied is the same in all (so far as I can learn), viz., that of applying the force to the air from the body of the gas-vessel itself, about the plane of its equator. Instances of this are the following: Mr. John Lake proposed, in a letter in the 'Mechanics' Magazine' (1837, No. 706), to force, by a fan or otherwise, a stream of air from a tube opening at the hinder part of the eggoon. M. Sanson, in several not very intelligible pamphlets published in Paris between 1839 and 1850, has described a contrivance, by which he conceives that he has solved the problem of aerial navigation—an 'atmospheric ship' furnished with certain paddles and flappers attached to an 'ellipsoidal lenticular' gas-vessel. Finally, in the summer of 1850, a long fish-shaped model air-craft was exhibited in Paris by M. Jullien, a poor hard-working mechanic in a country village in France; this was actually driven through the air by a pair of oars, or screw propellers, attached to the forepart of the framework of the apparatus, about the level of the equator of the fish, and they are reported to have done their work well.[2]

If the purchase could thus be taken from the gas-vssel itself on the level of its horizontal axis, there is no doubt that the diffi-

[1] M. Marcy Monge is a remarkable instance of this; in his most interesting work 'Études sur l'Aérostation,' in which he endeavours to discuss fully all the conditions necessary to aerial navigation, no notice whatever is taken of this twisting tendency, and loss of power as a result to be avoided. He sums up the essentials of aeronautics in ten conditions ('Etudes,' p. 8) which he treats severally at length; but this vital point, that the propelling force should be applied in the proper direction, is not among them.

[2] An engraving of this model, which is the best hint as to the future of aeronautics, that I have been able to hear of, will be found in the French newspaper 'L'Illustration' for November 15–22, 1850, p. 309: and an interesting account of it in Turgan's 'Les Ballons,' p. 197.

culty would be quite surmounted. But I fear that, on the large scale, it would not be found practicable to transmit the force from the boat below to the equator of the envelope; and that this objection would be found fatal even to the very skilful device of M. Jullien.

Mr. Sadd, of Wandsworth, proposes to get the power applied in the right direction by a very clever design, to which this objection does not apply, and of which he has made two or three models. His apparatus consists of two cylindrical gas-vessels, terminated at each extremity by cones, and attached together side by side, supporting between them a frame work, which carries the passengers, and the feathering paddle wheels, by which he proposes to propel the system. The apparatus resembles a donkey, with an enormous pannier on each side of him [1]—panniers, however, that, instead of loading the working animal, would relieve it of the most oppressive burden, that of itself.

If this method of suspension can be adapted to gas-vessels of large size, it will undoubtedly get rid of this fundamental difficulty. But I should fear it would not be found to answer. Firstly, because for a given bulk of gas, a much greater extent of envelope is required, than if the gas is contained in a single vessel; and this not only adds to the weight very much, but increases the amount of surface and consequent liability to leakage.[2] Secondly,

[1] I believe that no description of this very ingenious contrivance has been published, except in a report of a lecture (of which it formed the subject) given at Croydon by Dr. Longstaff. This may be found in the 'Sussex Agricultural Express' and 'Surrey Standard' newspaper, September 22, 1849, p. 6, col. 4. Mr. Sadd is a working shoemaker, and the enthusiasm and skill which he has bestowed on his aerial schemes did not prevent his industriously plying his more terrestrial craft in pursuit of his daily bread.

[2] It is of course necessary that there must be a communication between the twin gas-vessels; otherwise, one, by leakage or diffusion, might lose buoyancy more quickly than its fellow, in which case the apparatus would float lopsided. But even with several free channels between the two, it would most likely be impossible to maintain similar atmospheres for any length of time within the two envelopes; for without some special contrivance for keeping up a constant current from one to the other, it would scarcely be possible to ensure the two atmospheres, mixing to constant uniformity, more rapidly than any difference in the texture of the envelopes

because the man-vessel is brought very near to the gas, which, if possible, should be avoided, on account of the risk from fire, or of the necessity of abstaining from its use. Thirdly, because the chief weight, and consequently the centre of gravity of the system, being brought so high, the stability of the apparatus in a horizontal position must be very precarious. Fourthly, because the twin form has been tried in aquatics, and not having been found advantageous, has fallen into disuse.[1]

I should be guilty of great injustice if, by omitting to make further mention of Sir George Cayley in this place, I should seem to class him among the aerial projectors who have ignored the difficulty which I have been discussing. I said in my preface that, there being an oversight in the arrangement proposed by this gentleman for his air-craft, which would have been fatal to its success at first, I did not consider that he had fully solved the problem of aerial navigation. It was what seems to me a mechanical mistake on his part, as to this very point, that compelled me to make this reservation, and prevents me from putting him in the category of inventors who have endeavoured to surmount this stumbling-block of aeronauts. Sir G. Cayley was well aware that

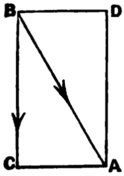
might allow their contents to be altered by accidental loss of gas, and entrance of air. Again, if, the gas-vessels having free communication, one of them did fall below the other, the difference of buoyancy would tend to be increased by the flow of the light gas from the lower into the upper one —a process which would lead to a most fatal change in the position of the system. I have been led to make these remarks from a motive the very opposite to that of wishing to find fault. I have considered Mr. Sadd's invention at greater length than others which I have had occasion to mention, because it deserves to be more publicly known than its author had facilities for ensuring; and because it is really worth criticism, which is more than can be said for some of those schemes in connection with which I have had occasion to mention it.

[1] It has been essayed not only in human water-craft, but in organic nature, in a single species, which has only been imitated by such eccentric developments as the Siamese twins, whose arrangements would be inconvenient in common life. This queer creature rejoices in the name of Diplozoon Paradoxum, and may be found on the gills of the fish Bream, and on p. 92 of Professor T. Rymer Jones's 'General Outline of the Animal Kingdom.' If this double structure had any general utility, it would no doubt have been repeated, for our instruction, in other forms of life.

the difficulty was supposed to be in the way, but he conceived it to be only supposed, and not real; and he gives a geometrical expression of his view.[1]

The following is the substance of his argument. Let A (fig 7) be the position of the boat: B, that of the gas-vessel after the commencement of motion. The whole force that is acting at A is transmitted to B in the direction of B A; let the length of A B be taken to represent the magnitude of this force. Through A draw A C, A D, horizontal and vertical respectively, and complete the parallelogram of which A B is the diagonal. Now the force B A acting at B, is equivalent to two forces acting in the directions B C, B D, whereof each is respectively proportional to the length of the lines B C, B D.

Fig. 7.



The force B C acting downwards is the weight of the car, which is just balanced by the buoyancy of the gas, and the force B D is the propelling force acting in a horizontal direction, which latter is in equilibrium with the resistance of the air, as soon as the speed becomes uniform; and B D is equal to C A, which represents the horizontal force acting at A, therefore the force acting at B is the same as that exerted at A, both in amount and in direction; so that the whole of it is as much available for the direct propulsion of the gas-vessel, as if it were applied immediately to that part of the system.

Now this is perfectly true of such a simple system as that of the diagram in which the forces are supposed to be acting upon mere points, or of one in which the force could be transmitted through a single cord: it is even true of a balloon and car, but only in the case in which the propelling force is made to alter its line of action with respect to the car, and to maintain a true horizontal direction. For when, by the first twisting motion, the car has assumed its position of equilibrium, the force is communicated to the balloon by all the cords alike, and the condition is virtually the same as if the car were suspended by a single cord; and with the balloon, the resistance it encounters at a given velocity is equal, whatever may be its position. But even with

[1] 'Phil. Mag.' vol. 50, p. 31, and 'Mech. Mag.' vol. xxvi. p. 426.

the advantage of this adjustment of the instrument of motion, the statement does not hold good with respect to an elongated oval vessel, which is the form proposed by Sir G. Cayley. For, with such a system, no sooner does motion ensue than the conditions of resistance are changed. From what has been said before, it will be evident, that as soon as the driving force acts on the boat, the apparatus will take a position more or less like that represented in fig. 8. If the force act along the length of the boat, as in the line A C, an upward slanting motion will ensue, as before explained. If, however, its direction be accommodated to the new bearing of the craft, and be made to act in the horizontal line A B, it is true that the whole force is exerted in the required direction, but it meets now with a vastly increased amount of resistance, namely, that provoked by the long under surface of the gas-vessel, instead of that due to its narrow end,

Fig. 8.

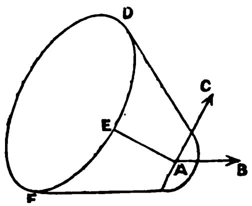
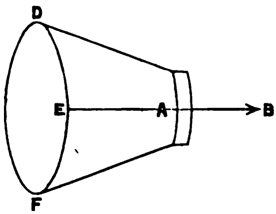


Fig. 9.



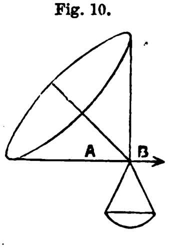
which was fashioned for cleaving the air. Now, if this horizontal force be infinitely great, it will bring the system into the position in fig. 9, in which it will encounter the full effect of the direct resistance due to the whole largest section of the oval; but if any practicable degree of force be exerted, the position will be that shown in fig. 8, in which the surface D E F sloping upwards will act as the inclined plane of a kite, and will resolve the pressure it receives from the air partly into an upward direction. This will cause the system to mount, thus wasting a share, more or less great, of the force, in producing a useless ascent of the vessel, and this motion, compounded with that in a horizontal line, due to the unresolved propelling force, will result in an upward slanting path in the diagonal direction.

It thus appears that in no case in which the mode of suspen-

sion proposed by Sir G. Cayley is adopted, does his diagram give a correct representation of the conditions; and that his reasoning does not apply to the form of apparatus which he designed.

But without having traced these results, it might have been sufficient to remark, that no method of suspension and propulsion would be admissible in practice, in which the man-vessel were liable to any such tilting out of the horizontal set, as would be given to it under the circumstances here proposed. It is absolutely necessary that the boat should be maintained in a strictly level position, or, that at least this condition should not be liable to any considerable derangement: for, without constant horizontality there would be neither comfort nor safety for the passengers. It would therefore be necessary not only to maintain the action of the propelling force in a horizontal direction, but to suspend the boat so that it would hang in a true level. Now, with the proposed arrangement of the cords from the gas-vessel, this could only be done by balancing the boat on a horizontal axis placed considerably above its centre of gravity, or by hanging it by diverging cords from a single point, or from a horizontal line at right angles to the direction of motion, in which (as at the hoop of the balloon,) the converging net ropes should be collected, and from which the driving power must be applied. And even by this mode, perfect horizontality of the boat could not be ensured, unless the resistance of the air to its bows was practically nothing.

Fig. 10.



But in this case the gas-vessel would be equally thrown out of its position of least resistance—the system assuming the form shown in fig. 10—as soon as motion commenced. In this fig., B being the point of suspension and of application of the force, and A B the direction of the force, constantly horizontal, it is evident that the same conditions obtain, so far as the force and the gas-vessel are concerned, as were previously discussed and represented in fig. 8.

I have entered at considerable length into the consideration of the state in which this question of the application of the propelling power stands at present, as left by those who have previously touched upon it. I have done so because it concerns

one, if not the chief of the difficulties of the art, and because I have not met with any full examination of it by any other author, though the results have often been stated generally, and because, so far as I can learn, it is a problem which has not yet been satisfactorily solved.

In the second part of the book I shall show how I believe the knot may be untied in a very simple manner, which seems somehow or other to have escaped those who have hitherto taken it in hand. We have now, however, arrived at a point which enables us to state some of the essential conditions of aerial navigation, viz.: *That the propelling power must be so adjusted that it may be kept constantly horizontal, and that the force must be so applied that it shall have no tendency to make either gas-vessel or man-vessel deviate from a strictly horizontal position, and this, whatever may be the speed of flight.*

CHAPTER IV.

THE SECOND DIFFICULTY: THE GAS-VESSEL—ITS STIFFNESS.

The stumbling-block of the threshold which has been discussed in the last chapter—the loss of force exerted in the boat hanging from the gas-vessel—is very closely connected with another difficulty, the apparent necessity of overcoming which in a particular manner has thrown the inventors upon the former obstacle.

The resistance of the air is supposed to be the aeronaut's greatest enemy. This is a very great mistake. I hope to show that it is his best friend and very ground of hope. But this much is certain, it is a friend that must be discreetly treated. It is then necessary that the form of the gas-vessel must be that best suited to humour the resistance of the air. What this form is, has never been determined. It has only been shown that the sphere, or balloon, is a very bad one, and there is not much reason for supposing that the eggoon is very greatly better. I am not about to consider, in this place, what the form should be, but to show into what dilemma the aerial navigators have been cast, in their endeavours to adapt to their purpose the best forms they could get. It was agreed by all, that the form must be a long one of some kind—a cylinder terminated by hemispheres or cones, a long egg shape, a fish shape, a 'prolate spheroid,' a 'lenticular ellipsoid,' according to fancy—but it must be long; but not, it appears, very long. There are two objections to this. One of these, which refers to the difficulty of keeping long figures poised in a horizontal direction without upsetting, I shall have to consider hereafter. The other objection is a very obvious one—the difficulty of keeping firm and stiff, long figures of flexible materials. It is

quite evident that, if a moderately long bag be filled with light gas, and have a weight suspended beneath its middle as in fig 11, it may rise and retain its shape, so long as it be so full of gas as to keep its surface stretched and tense. But the envelope will not always be full enough to keep it tight; for instance, by loss of gas it may become flaccid, and this will sometimes be inevitable, or it may be required to charge it incompletely, which will be advisable if it be desired to rise a great height in the air, with a load lighter than the full tonnage of the vessel. Now in such a case it is clear that, if the weight be suspended from the middle of the gas-vessel, and if the ends are free, they will turn up, by reason of the rising of the light gas (like a certain ill-looking black beetle which turns up its tail with a spiteful air if you touch it), and the apparatus will assume some such form as that represented in fig. 12. Now the necessity of having a more or less elongated form was undoubted, and therefore this difficulty was to be got over. Now, one means of remedying it was so obvious, that indeed it perhaps was adopted instinctively by the first persons who substituted an eggoon for a balloon, without the difficulty itself which would have attended its omission ever presenting itself to their minds. And this is the more likely to have been the case, as the method alluded to is, in fact, nothing but the adaptation to the egg-shape of the appliances already in use with the original globe. It is the enclosing, or at least the covering, the envelope with a netting, from which, at points all round the horizontal section of the gas-vessel, cords are brought to the boat. By this means the weight of the man-vessel is distributed over the whole upper surface of the envelope, ends as well as middle, and the cords A B, C D, and those near them, act as stays, to prevent the turning up of the head and tail of the gas-vessel.

Fig. 11.

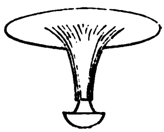


Fig. 12.

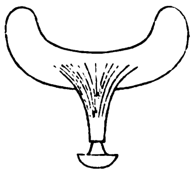
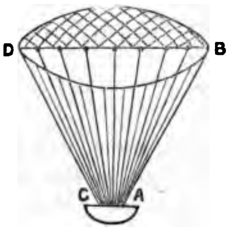


Fig. 13.

The netting and its ropes have been looked upon as a sort of inalienable appurtenance to the balloon; which, like a membrane investing the egg contents, has clung móst pertinaciously to the hatching chick, and clogged all its struggles for free life. There has scarcely been one aerial schemer who has ventured to try to rid himself of its meshes. The net sprung at once, with the valve and ballast, from the fertile brain of M. Charles,[1] as the complete rigging of the balloon and car. These three contrivances were found to answer all the purposes for which they were designed, and have kept their place ever since, as the sacred implements of aeronauts, of which it seems a kind of treason to doubt the efficacy and necessity. But, whatever may be the utility of the other adaptations made by this most ingenious man, I have no hesitation in asserting that aerial navigation can never advance one step, till net, waste valve, and waste ballast are, if not utterly discarded and left to the balloon, at least reserved for other and secondary purposes, and no longer relied upon as the essential agents of equilibrium. At any rate, it is this traditional adherence to the net and cords which has placed aeronautic inventors in the first chief difficulty which I have been discussing at length. It relieved them at once from the one horn of the dilemma (the upturned ends), and has left them hanging ever since on the other and more perplexing alternative (the tilting tendency of the force in the car). In short, these very cords, which seemed so necessary to keeping the gas-vessel in shape,

Fig. 14.

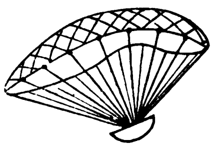


[1] 'Pour cette première ascension Charles créa, tout d'un coup et tout d'une pièce, l'art de l'aérostation. En effet, c'est à ce sujet qu'il imagina la soupape qui donne issue au gaz hydrogène et détermine la descente lente et graduelle de l'aérostat—la nacelle où s'embarquent les voyageurs; le fillet qui supporte et soutient la nacelle; le lest qui régle l'ascension et modère la descente; l'enduit de caoutchouc appliqué sur le tissu de ballon, qui rend l'enveloppe imperméable et prévient la déperdition du gaz; enfin l'usage de baromètre qui sert à mesurer les hauteurs, que l'aéronaute occupe dans l'atmosphère.'—*Revue des Deux Mondes*, tom. viii. p. 207.

and which, with the aid of the net, answer that purpose so well when the eggoon is not a long one, is pretty well full, and is not disturbed by any horizontal force in the boat, are the very causes (as has been shown above) of the loss of power in twisting the system out of horizontal position, as soon as propulsion is attempted.

Again not only is there this fatal objection to the net and converging cords, as the means of suspension, but the use of them alone is sufficient to put a limit to the horizontal length of the gas-vessel, for it is quite evident that if the attenuation of the supporting vessel be carried far, and if it remain flexible, it would be bent, or even doubled up, as in fig. 15, as soon as the weight was thrown more upon one end than the other. And this unequal distribution of the weight would be the immediate consequence of the tilted position, which, as has been shown, is the inevitable result of propulsion from the boat when thus attached to the gas-vessel. Now, as I shall have presently to state more fully, the endeavour of the aerial architect must be to build his craft as long and narrow as possible, on the finest lines that are consistent with strength and stiffness. This, then, is another reason of itself sufficient for the rejection of this mode of rigging the air-craft.

Fig. 15.



The consideration of the object sought to be attained by the use of these cords diverging to the head and tail of the gas-vessel —of this martingale rig as it might be called—has led us to a second essential requisite in aerial gas-craft, viz.: *That the gas-vessel must be kept perfectly stiff, so that it shall neither turn up nor be bent down at the ends, but shall keep its form under all varying conditions of load from below, and of gas-charge within.*

I am not aware of any attempts that have been made to ensure this object, except the almost universal one just treated of, viz. that of tying down the ends by stays to the boat, and the few cases in which it has been proposed to make the gas-vessel of some but slightly elongated shape, and to stiffen it by means of a backbone or equatorial framework, with which the car is to

be either in rigid or flexible connection. Instances of this latter endeavour are the devices of Scott, Génet, Partridge, Sanson and Sadd, referred to at pp. 44–6. There are objections to each of these, some of which I have noticed already in the four first examples; others are either not worth mentioning on account of the absurdity of the errors, or would be out of place in this part of the subject. But the chief points in which they fail as regards the conditions of length and stiffness, which we are now considering, is that none of the forms of the gas-vessel proposed by the designers are long enough in proportion to their thickness to enable them to be propelled with any useful speed; and that if they were made sufficiently elongated, the method of stiffening proposed for them by their authors would be inadequate to maintain their shape.

Perhaps one other method might be mentioned, which has been frequently proposed, and by which, if it were successfully applied with a proper method of suspension, this object of rigidity for the gas-vessel would be in some degree attained. I refer to the proposal to keep the gas-vessel perfectly filled with gas somewhat condensed by pressure. The increased elasticity of the contents of the envelope would, by stretching and tightening it, confer on it a certain amount of stiffness. But this has not been the chief aim of those who have suggested it, and its consideration naturally following in this connection belongs rather to the discussion of the special object for which it has been proposed, and which I shall next proceed to treat.

It does not then appear to me that any method has yet been proposed for keeping the gas-vessel inflexible, which will fulfil that condition when the envelope is of proper form, and the usual vicious mode of suspension is discarded. I shall hope to show hereafter by what means this essential requisite may be completely satisfied.

CHAPTER V.

THE THIRD DIFFICULTY: THE GAS-VESSEL—ITS FIRMNESS.

It is generally admitted that if a flexible bag, filled or nearly filled with gas, be forced to move through the air with velocity, the pressure of the air on the fore-end of the vessel would press the envelope inwards so as to form a concavity. It is therefore said that it is necessary to provide means of enabling the bows of the gas-vessel to resist the pressure of the air.

I conceive this to be quite true. It has, however, been disputed by a gentleman who some years ago paid much attention to the subject of aeronautics. The following is Mr. Monck Mason's statement and argument in refutation of this view:

'One of the most specious of these misconceptions regards the effects of the resistance of the atmosphere upon the figure of the balloon when rapidly propelled through the air, whereby it is presumed its opposing front will be driven in and more or less incapacitated from performing the part assigned to it; namely, to cleave its way with the reduced resistance due to its proper form. To obviate this imagined result, various remedies have been proposed; such as to construct that part of the machine of more solid materials than the rest, or else (as suggested by one of the most scientific and ingenious of those who have devoted their attention to the theory of aerial navigation) to subject the gaseous contents of the balloon to such a degree of artificial condensation by compression, as shall supply from within a force equal to that from without; adopting of course materials of a stronger texture than those at present in use for the construction of the balloon.[1] Now the contingency against which it is here

[1] This refers to Sir G. Cayley, whose remarks upon this subject, and the means whereby he proposes, as above stated, to fulfil the requisites

sought to provide, and which I grant is a very reasonable one to anticipate, has nevertheless no real existence in practice; at least, in such a degree as to render it necessary to have recourse to any particular expedient for its prevention. Taking it for granted that the hypothesis in which it is involved is founded upon a presumed analogy with a balloon exposed to the action of the wind, while in a state of attachment to the earth, I would first observe that the cases in question, however apparently analogous, are in reality essentially dissimilar. In the one case (that where the balloon is supposed to be attached to the earth) all the *motion*, and consequently all the *momentum*, is in the air; in the other case (where the balloon is supposed to be progressive) it is in the constituent particles of the machine itself and of its gaseous contents. And this momentum, which is ever proportioned to the rate of its motion, and consequently to the amount of resistance it experiences, is amply sufficient to secure the preservation of the form of its opposing front, however partially distended, and whatever the velocity with which it might happen to be endowed.'[1]

I have cited this paragraph at length because it fully states the view generally entertained, and clearly lays down the ground on which the writer rejects it, and maintains the admissibility of a flexible yielding gas-vessel. In a passage immediately following that which I have quoted, it is asserted that practical experience had confirmed the theoretical conclusion just before deduced; but as the author does not describe any experiments made to ascertain or illustrate the fact, I do not conceive that he adds anything to the strength of his position by the statement.

of the case, will be found in 'Phil. Mag.' vol. xlvii. p. 84 (Feb. 1816), and in 'Mech. Mag.' vol. xxvi. p. 419 (March 1837).

[1] 'Ellips. Ball. at Adel. Gall.' p. 16. The name of the writer is not attached to this pamphlet, but it is a description by the author of 'Aeronautica' of a model air-craft of his contrivance, which was publicly exhibited in London in 1843. In the volume last mentioned (p. 330, &c.), which was published in 1838, Mr. Mason expresses himself as despairing of any realisation of aerial navigation. But experiments subsequently made led him to the different and hopeful view expressed five years afterwards in the pamphlet above quoted.

I do not, therefore, further quote his words. I do not remember to have met with any other writer (advocate or opponent) on aerial navigation who has maintained this view.

The disputed point, however, is one of great importance in aeronautics. An accurate conception, therefore, of the state of the bodies concerned under these circumstances, is quite necessary in seeking to determine the requisites of the art. The analogy between the case of the wind acting on a balloon forcibly retained at rest, and that of the gas-vessel propelled against the air, is denied, on the ground that it is only the gas that is in motion that is endowed with *momentum*, and that because this *momentum* is proportional to the resistance, it is therefore capable of preserving the form of the envelope. Now, though the external air when at rest has no *momentum*, it has *inertia*, by virtue of which it exerts a pressure on the gas-vessel, which in endeavouring to cleave its way through the air sets it in motion. But the envelope is moving with exactly the same velocity as the gas which is within it; therefore this gas cannot exert any pressure on any part of the envelope which it did not exert when they were both at rest. Now when they are at rest and prevented from moving, the wind blowing upon the gas-vessel will cave it in like a cup, not only if the envelope be but partially, but even if it be completely full. In this latter case the contained gas will be condensed to a degree corresponding to the pressure exerted by the wind. The conditions are precisely the same if the gas-vessel and its contents are in *uniform* motion. The fore end of the envelope is always running away from the gas, and the hinder end after it, at exactly the same velocity as that with which the gas is moving. The gas cannot, therefore, exert any more pressure at the bows than at the stern of its receptacle. When the motion is accelerated or retarded, the case is different. In either case the solid envelope receives the check first, while the *inertia* of the gas within, which is free to move, carries it forward with the same velocity with which it was progressing before, and therefore exerts pressure on the hinder or forward end of the vessel according as the change is one of increased or diminished speed. But in either case it only continues this pressure until it has

acquired the same velocity as that of the solid material which surrounds it.

A simple illustration will suffice for those who are not accustomed to a dynamical phraseology, and will, by appealing to the mechanical instinct, which everyone possesses more or less, be more convincing than any technical demonstration. Of course a basin of water on the cabin table in a steamboat is in conditions, as respects the forces acting on it and which it exerts, exactly analogous to those affecting the gas in a locomotive gas-vessel. When it is at rest the liquid in the first case presses on the sides and bottom of the basin, and the fluid in the second case presses on the sides and top of the envelope. Not more, in either case, on one side or end than on the other. Let now the steamer be in *uniform* motion at any speed, no matter whether one or ten miles per hour—will the water in the basin be pressing more against the forward side of the basin than against the after part? or more against either of them than when it was at rest? I do not think any one will hesitate to answer in the negative. If there should be a doubt on your mind, reader, consider whether the water will lie with a level surface or not in the basin. If there be a pressure forwards, the surface will not be horizontal, but will be sloped by the liquid running up the forward side of the vessel. If the ship suddenly obeys orders to 'back her,' this will actually ensue, but I think you will at once decide that it will not occur while she is going ahead with unvarying speed.

It is evident, then, that when the air-craft is in uniform motion, no pressure is put forth by the gas which it does not equally exert when at rest. Again, when the gas-vessel is moving onwards at any given speed, the air without exerts upon its prow a pressure of exactly the same amount as that with which a wind moving with the same speed would urge it if it were fixed to its place. Now the wind would cave in the gas-vessel if at rest; the envelope would therefore suffer equally this injurious alteration of its form, if it were impelled against the air without some special means of resisting the effect.

It may therefore be stated as a third essential requisite of aerial navigation, *that the gas-vessel must be provided with means of resisting the pressure of the air, at least upon its anterior sur-*

face. There is no doubt, too, that this same aid would be requisite in some degree for the other parts of the envelope, for the currents of air rushing about the hinder end would no doubt tend to alter its form in some degree, and might do so detrimentally if it were unable to resist their influence.[1]

Two methods, as was stated in the above extract, have been proposed for securing this end. The first of these is that of providing the fore end of the gas-vessel with a shield or cut-air, of rigid materials, adapted to resist the pressure of the opposing atmosphere. Such shield may be formed either by giving a separate covering to the bows of the vessel, or by strengthening the texture of the envelope itself at that part. Instances in which the former appliance has been suggested may be found in a 'Description of a Proposed Flying-Machine,' by Dædalus Britannicus,[2] and in the 'Aérostat Dirigeable—Système Physique, Mécanique, Ptérophore, Dynamique et Trigonométrique' of M. M. Sanson,[3]—before noticed.

Of the other form of this first method, the only example with which I met is that of M. Marcy Monge's proposal to form the vessel itself of material endowed with some degree of stiffness.[4] The view of this author, however, is that the whole envelope should be made of metal or of pasteboard. I shall have to speak of this at greater length in treating of the requisites in the material of the gas-vessel. But the means upon which he relies for encoun-

[1] In real truth, if there is any increased pressure from within at one end of the gas-vessel more than another, it will be in the case of a short eggoon, which was the form of vessel with respect to which Mr. Mason's remarks were made—at the tail end, not at the head. For if any body is rapidly moved through the air, it tends to condense the elastic fluid in front of it, and to rarify that behind it; the consequence of this state of things must be, that if the body is not of an elongated figure, so as to fill up as it were by its tail the vacuum behind it, the gas within, being relieved of resistance, will expand in that direction, and will press upon the envelope which restrains it.

[2] Dæd. Brit. 'Aer. Nav.' (1847) frontispiece (a pamphlet of 16 pages—not altogether wise in its details, but containing fewer absurd notions than are to be found in many aeronautic schemes, and a few very good ones).

[3] Sanson 'Explic. Navig. Aér.'

[4] Monge, 'Etudes,' p. 25.

tering the resistance of the air is the second mode—viz. that of keeping up a pressure within the envelope—which we will now proceed to consider.

The application of pressure to the contents of the gas-vessel, so as to vary the degree of its elasticity, has been very frequently proposed by speculators in aerial navigation ever since the first experiments with the balloon. Two ends have been sought by this contrivance: one, that which we have before us at present; the other, the condition which will come next under review, that of altering the equilibrium of the gas with respect to the surrounding air. The first proposer of condensation within the gas-vessel in a manner adapted to the maintenance of a firm exterior, was one of the earliest and most earnest enquirers into the means and requisites of aeronautics—General Mensnier. The method which he devised was intended to serve likewise the other purpose, of diminishing or increasing the lifting power of the gas-vessel, without loss of either gas or ballast. His envelope was to be double, one case within the other, the inner one to contain the light gas, the outer one to be stouter and stronger, so as to resist pressure from within. The outer case was to communicate by tubes with bellows worked in the boat, by means of which air might be forced into the space between the two vessels, so that when the tension of the gas-bag should be diminished by loss of gas, the outer envelope might be kept tight by the renewed pressure of the injected air.[1]

Sir George Cayley has insisted much on the necessity of this pressure from within being given to the gas-vessel.[2] He proposes to effect this in the case of hot-air vessels, by suspending the fire at a considerable distance below the receptacle, with which it is to communicate by a long chimney. And in the case of envelopes for light gas, he mentions the alternatives of a supply of the gas itself injected into the envelope of a double casing with air to be forced between them, and of a small balloon within the gas-vessel to contain air, thrown in under a certain pressure.

[1] Monge, 'Études,' pp. 58, 101.

[2] 'Phil. Mag.' vol. xlvii. p. 84, and vol. l. p. 34; and 'Mech. Mag.' vol. xxvi. p. 419.

Very recently again, Mr. Bell, in the specification of a patent 'for certain improvements in aerial machines, and in machinery in connection with the buoyant power produced by gaseous matter,'[1] 'claims the application of one or more flexible partitions, which he terms "septum membranes,"' 'into the space beneath which air should be injected by a blowing machine . . . . to obviate the otherwise flaccid state into which the balloon would fall.'[2]

A different and truly original plan is contended for by M. Marcy Monge,[3] who insists very strongly on the necessity of the '*pression intérieure.*' The quantity of the contents of his gas-vessel is not to be kept constant; but as the contents diminish by leakage, the volume of the vessel is be altered by compressing it along its lower part between a pair of wooden squeezers, worked from the boat by means of cords and appropriate mechanism. Sir G. Cayley and M. Marcy Monge[4] have recorded the results of experiments upon the strength of envelope materials made by themselves on caoutchouc, cotton, cloth, and on thin brass plates, respectively, with a view to determine the amount of pressure from within that could be borne by gas-vessels. M. Monge in particular has treated the subject at considerable length.

Now it is with reluctance that I have again to confess my

[1] Enrolled May 23, 1849, in the Enrolment Office.

[2] 'Patent Journal,' June 16, 1849, pp. 92, 94.

A very excellent piece of counsel is given to aerial speculators by M. Dupuis Delcourt in a recent contribution of his to the literature of aeronautics—hints which those who intend their speculations to be golden as well as airy, will do especially well in following before they hurry across the treacherous frontier of patent-land.—'L'aéronaute, qui veut être de quelque utilité à l'art, doit faire des recherches étendues, qui lui fassent connaître ce qu'on a dit, fait, ou écrit sur les aérostats: c'est la seule manière de ne point s'exposer à travailler inutilement sur des idées rebattues. Ce défaut de connaissance du point où en est l'aérostation aujourd-hui, a rendu inutiles et même nuisibles à l'art la plupart des expériences et des prétendus essais de direction, qu'indiscrètement, pour ne pas dire plus, on a offerts au public.'—Delcourt, *Manuel*, p. 138.

[3] Monge, 'Études,' pp. 55, 59.

[4] 'Mech. Mag.' vol. xxvi. p. 419, and Monge, 'Études,' pp. 64, 296.

dissent from the opinion of an authority to whom I have had frequent occasion to refer with respect; but I must say that I do not consider the maintenance of internal pressure to be the most effectual means of meeting the crushing effect of the air upon the bows of the gas-vessel, for these reasons:—Firstly, the greater the compression to which gases are subjected, the greater will be their effort to escape; and this will be especially prejudicial in the case of the subtle hydrogen, whose diffusive power is already so great that it requires our best endeavours to resist it; so that we should be cautious in adopting towards it any treatment that might aggravate its intractability.[1] Secondly,

[1] It is very true that the tendency of gases to diffuse one into another is inversely proportional to the square roots of their densities; it might be supposed from this that the power of gas to escape would be the less the more it was condensed, according to the same law. This is clearly not the case, because the elasticity is increased by condensation, and this increases the efforts of the fluid to escape. If the gas-vessel were entirely surrounded with an outer envelope, containing condensed air, so that the compressed gas would have an equally elastic, but denser atmosphere to diffuse into, the case might be altered. But whether the diffusion of the two into each other would be favoured or retarded by this condition, must be ascertained by experiment, not predicted. I believe it has not yet been learned whether, or if at all, in which sense, barometric, or greater changes of pressure alter the relative diffusion, volumes, and times of gases. Mr. Graham makes no mention of any facts as to this point, in his latest summary of his researches on these properties of gases. (See his 'Elements of Chemistry,' 2nd ed. vol. i. p. 84.) But in fact the inner gas-vessel never could be thus surrounded with condensed air; it would have an atmosphere of such air below it, and above would be pressing its own upper side tightly against the top of the outer envelope. It would thus have to diffuse into air equally condensed with itself through a single diaphragm below, and above would have to find its way through two coverings into air of the ordinary pressure.

In experiments and considerations on the diffusion of gases under pressure, it must be borne in mind that to the two cases of both, and of only one of the gases being under variable conditions of pressure, there is added a third, by the possible differences in the quality of the diaphragm. If this be flexible, and can be stretched by the elasticity of the gas within, its permeability will be increased by the enlargement of its minute perforations, when the pressure of one side is greater than on the other. If the gases on both sides of the extensible membrane are under pressure, the conditions will not differ from those obtaining when the diaphragm is sti.

this method implies the suspension of the boat to a support made of flexible and yielding materials, a condition which I cannot consider suitable to the firmness and stability which are desirable in a locomotive vehicle purposed for human transport, and liable to shocks and casualties which might endanger the safety of a frail fabric. Thirdly, although the adoption of this means would fulfil the design for which it is intended, if the receptacle is not much elongated, is furnished with converging end-stays, and is propelled by power taking purchase from its own equator, it would be quite inadequate to the purpose if the gas-vessel is of great length in comparison with its thickness, which is an essential requisite to rapid motion, and if it is to be urged by force applied to the boat, which is the safest and simplest mode of exerting it. At least, it would be inadequate, without the aid of other appliances which would render it either unnecessary, or far less convenient than a slight addition to other parts of the apparatus. Fourthly, a reliance upon this mode of resistance would keep the system ever in precarious dependence on a varying influence, for the maintenance of a state which ought to be, and can easily be made, absolutely constant, as one of the essential conditions of its motion. Fifthly, the detrimental action upon the whole apparatus of buoyancy, of an accidental weakness in any one part, which, from the unavoidable imperfections in work, must necessarily be found in all large surfaces of their textures, would either be very much exaggerated under circumstances of pressure, or would be entirely fatal to the efficiency of the contrivance. Sixthly, the use of this method would have, by exerting a constant strain on the material of the envelope, a constant tendency to weaken its texture, and to impair its ability to execute its special function, that of preventing the escape of gas, and of keeping it from mixture with atmospheric air. Seventhly, this plan of not admitting any expansion of the gas within its envelope, involves either loss of gas, and of buoyancy, on rising from one region to another of less barometric pressure; or at least this loss can only

and unyielding, as the texture will not be stretched at all. The three cases then are: 1st. Both gases under equal pressure. 2nd. The two under different pressures with unyielding diaphragm. 3rd. The two under different pressures with extensible membrane between.

be prevented by the use of an additional gas-vessel to receive the gas as it escapes, a complication that would be extremely inconvenient in practice.

I am entirely in favour of the shield plan. But none of those of which I have found descriptions seem to me to combine all the requisites of the case in a good working form. I shall hereafter describe the combination which I believe to be most suited at once to secure this end, and some of the other essentials of the art.

CHAPTER VI.

THE FOURTH DIFFICULTY. THE RISING AND FALLING OF THE AIR-CRAFT.

In speaking of the condensation of gas or air within the envelope for the purpose just discussed, I mentioned that its use had been suggested for another purpose—that of altering the equilibrium of the system with respect to the air in which it is floating, and to gravity. The consideration then of this subject—the only one of balloonera, a chief one with aeronauts—naturally follows in this place.

It was a second triumph for poor Pilatre de Rozier and the Montgolfiers, when the former—a really intrepid man—found that he could raise or lower himself in his 'fire balloon' by increasing or allaying the briskness of the flame in his hanging grate.[1] It was probably the greatest check that the progress of aeronautics has yet received, when the same De Rozier, in his attempt to cross from Calais to Dover by the joint aid of hot air and of hydrogen, met with his death by some accident to the mechanism of the gas balloon.[2]

This was a most scientific adaptation of means to an e

[1] 'St. Fond. Exp.' vol. i. p. 274.

[2] It is generally stated in Histories of Ballooning that the fall of the apparatus and of the two voyagers it carried, was owing to the apparatus taking fire by the inflammation of the combustible gas. (Foster's 'Ann. Aer. Voy.' p. 28; Mason 'Aeron.' p. 273.) This is an error; there was no trace of conflagration on the wreck of the balloon when it was found, the fire had not even been lighted in the brazier; it appeared that the valve must have got deranged by some mismanagement, and the gas escaping, the whole vehicle was precipitated to the earth. ('Rev. des deux Mondes,' vol. 8, p. 221; Turgan, 'Les Ballons,' p. 121.)

which they were admirably suited to accomplish. It is probable that the apparently, but not necessarily, dangerous character of the experiment, coupled with the false report of the termination of this first attempt, has deterred ballooners in general from undertaking its repetition. Count Zambeccari, however, appears to have had sufficient hardihood to try what could be done with hydrogen and fire; and he, it seems, really fell a victim to his temerity, or to his want of skill in putting his conceptions into execution. I am unable to find any exact account of his contrivance; but from the various scattered notices of his feats and death, I gather that he used a lamp charged with spirits of wine for the dilatation and contraction of the contents of a balloon,[1] for the purpose of rising and falling in the air; but whether it was the hydrogen of his main balloon which he subjected to heat, or whether he used air in a separate vessel for this purpose, I am unable to learn.

However, the addition of the expanding power of heat to the buoyancy of light gas has not been forgotten altogether by aeronautic inventors. Sir George Cayley shows the utility in certain cases of uniting a hydrogen and a hot-air balloon,[2] though he does not recommend it for general purposes. And M. Marcy Monge, after speaking of the fate of the first aeronaut, which he erroneously attributes to the ignition of his gas, remarks, 'Cette catastrophe doit plutôt faire condamner l'imprudence que l'idée de Pilatre de Rozier.' He then proceeds to show [3] how useful a small hot-air vessel, cylindro-conic, would be as an appendage to his hobby—a cylindro-conic gas-vessel—of which latter more hereafter. The other and far simpler mode of applying heat as a supplementary agent for occasional use to the light gas itself, has been, if not used by Zambeccari, at least suggested by other schemers. Dr. Polli describes a method which he conceived for the expansion at will of the inflammable gas within the envelope. The gas-vessel is traversed from bottom to top by some zig-zag tubes, open at both ends, which form chimneys for the ascent of

[1] Delcourt, 'Manuel,' pp. 108, 111.
[2] 'Mech. Mag.' vol. xxvi. p. 421.
[3] Monge, 'Etudes,' p. 81.

the hot air from a lamp placed beneath in the boat, which is fixed by a framework to the gas-vessel.[1] One of the contrivances mentioned somewhat indistinctly by Mr. Partridge in his account of his 'Pneumodromon' is a 'calorator'—a system of thin metallic tubes and plates arranged within the lower part of the gas-vessel, into which it appears he intended to introduce, when expansion of the gas should be required, the waste steam from the engine, which was to drive the propellers.[2]

The objection to the double system of two vessels, one for gas and one for hot air, in aerial navigation, is, I think, not the danger but the complexity of the apparatus, and the far greater amount of surface of, and consequently of resistance from, the air to a pair of envelopes than in the case of a single one The latter fault does not affect the proposals of Polli and Partridge. I doubt whether either of them would communicate to the gas a quantity of heat sufficient for any useful purpose; and the latter is too complex a construction to be admissible within the gas-vessel. But the notion, which they are both attempts to embody, is, I believe, a sound and practicable one.

That the prodigal waste of power involved in the routine balloon practice of letting off gas or ballast, according as the fancy is to fall or to mount, is a vice in economy, or rather in aeronaunomy—for we shall not come just yet to make our dwellings in the air—not to be endured, must be one of the first thoughts that strikes anyone who reflects for a moment on the possible utility of gas-vessels in the construction of air-craft. It is so obvious a necessity of aeronautics, that we should at least be able to rise and fall without annihilating our power of remaining afloat at all, that scarcely anyone has ever written a few lines of hints on the matter without endeavouring to provide some better means of rising and falling than this piece of miserable make-shift or of reckless prodigality. Gas and ballast are the blood of the air-craft; to throw either of them away, except as the last resource for safety in case of catastrophe, is to be

[1] 'Observations on the Means of Directing a Balloon,' translated from the Italian of Dr. Giovanni Polli of Milan, 'Mech. Mag.' vol. xxxiii. p. 100 (No. 833).

[2] 'Mech. Mag.' No. 1032, pp. 401, 405.

likened to the old-fashioned practice of relieving a man of a pound of the staple of his life to save him from a passing pain.

To mention all the methods which have been suggested for the accomplishment of this first of purposes is far beyond my present object. I wish only to give instances of the principal ones. I have already said that condensation of gaseous bodies had been proposed with this view. This, as the principle on which it rests is obvious and elegant, has been one of the favourite plans, and has chiefly appeared under different forms, of which the following are instances.

The first endeavour to put this in practice was made by the two brothers Robert; they suspended in the interior of their hydrogen gas-vessel a small balloon intended to be charged with atmospheric air, which, if left free to escape, would be driven out by the expansion of the gas as the machine ascended, but which might be compressed at will by a blowing apparatus placed in the boat. They supposed that the additional weight thus made to occupy the same space, by condensation, which the expanded air did before, would be sufficient to enable them to descend, and that when the pressure was taken off, they would mount.[1] However, their contrivance was of no use to them when they essayed it (July 15, 1784).

This imitation of the fish's swimming bladder is too tempting not to have been again conceived; accordingly, a secondary air-balloon within the gas-vessel, for condensation, was adopted by M. de Lennox,[2] in his 'Eagle;' and was imagined by Mr. Partridge, for his 'Pneumodromon.'[3] It is evident that, in the case of these interior air-vessels, the pressure within them would not be communicated to the gas, unless the outer envelope were quite full and tightly closed, and the air-bag itself only partially filled. If either the latter were full and tense, or the former flaccid, the small bulk of air in the inner vessel alone would be affected by the condensation. For a demonstration of the utter hopelessness of this attempt, I must refer the reader to Mr. Monck Mason's

[1] Turgan, 'Ballons,' p. 88; Cavallo, 'Hist. Aerost.' p. 145.
[2] 'Mech. Mag.' vol. xxiii. p. 290; Turgan, 'Ballons,' p. 172.
[3] 'Mech. Mag.' No. 1032, p. 401.

'Aeronautica,' p. 385, and to M. Marcy Monge's 'Études,' p. 93.

A quaint scheme of this sort was put forth at Paris very soon after the first balloon experiment, by a certain Mons. B. He proposed to employ two balloons—the second hanging below the boat, and to be charged with air by bellows.[1] The variation of the density, and consequently of the weight of air, in this second balloon was to give the required change of rising power to the apparatus.

A scheme which was propounded by a writer in the 'Mechanics' Magazine' (vol. xxv. p. 293) may be here noticed, as being, in form and purpose, similar to the last mentioned, though it does not involve condensation of air. The lower balloon in this case was to be filled with carbonic acid, while the upper, as usual, was to be charged with coal gas. Of course the resort for rise and fall in this case is to the old waste of power, on a more extravagant plan than ever.

The elaborately designed project of Mensnier has been mentioned already; he intended to apply compression to the whole contents of the gas-vessel by means of air injected between the envelopes. This, of course, would produce a far greater amount of variation in specific gravity than any compression applied only to a smaller vessel, whether charged with gas or with common air.

M. Marcy Monge again, by his compressors before alluded to, proposes to alter the density of the whole contents of his gas vessel; but he shows that the amount of power so available is very small, and only speaks of it as an auxiliary agent.

M. le Baron Scott, in his scheme (1789) for a great aerial fish, proposed to furnish the envelope with some pockets,[2] which he supposed might be drawn in or out by tackle lines, so as to increase or diminish the capacity of the gas-vessel, and consequently to alter the specific gravity and lifting power of its contents at will.

The principle, however, of alteration of buoyancy derivable from change in bulk, and consequently of amount of air dis-

[1] 'Lond. Mag.' 1794, p. 13.

[2] Scott, 'Aér. Dirig.' pp. 66, 87, 110.

placed, has been suggested in a more likely-looking form by several persons. This proposal is to withdraw the gas from the float vessel, by pumping it into a strong receiver, kept in the boat, when it is desired to descend, and to allow it to escape into the light envelope when its lifting power is required.[1]

Most of the schemers who have suggested this method have been entirely ignorant of the conditions under which this plan would have to be applied, not being aware of the immense quantity of gas necessary to be condensed before a pound could be subtracted from the upward pressure of the gas, or of the enormous amount of mechanical force that would be necessary to condense it. With hydrogen it would be impossible in practice, even if any amount of power were available for the purpose, by reason of its unconquerable elasticity. With coal gas the case is so far different, that it will admit of being confined under greater pressure than hydrogen will endure. A writer in the 'Westminster Review,'[2] who is far less discouraging to aerial schemers than most of the orthodox authorities, proposes to take advantage of this, in one way, not hoping to condense it from the gas-vessel when afloat, but to have the work done at home, and to take a stock of liquefied coal gas in store in the boat, so that by letting some of it escape into the gas-vessel, an increase of buoyancy might be obtained when required. However, even coal gas does not afford such facilities as he supposed, even for the partial purpose here mentioned. Coal gas cannot be liquefied at a less pressure than that of thirty-two atmospheres, with the aid of a temperature about 160° below the 0° of Fahrenheit[3] (107° below 0° on the Centigrade Scale).

So much for rising and falling by mechanical condensation, and for the three forms in which it has been proposed—the condensing air into a bag,—the compression of the whole contents of the gas-vessel,—and the abstraction of some of its contents from the gas-vessel, and the condensation thereof in a strong receiver.

[1] 'Mech. Mag.' vol. ii. pp. 203, 221; vol. x. p. 206; vol. xxxi. p. 295; M'Sweeny's 'Aer. Nav.' 2nd ed. p. 32; Gire 'Mem. Aerost.' p. 7.

[2] 'West. Rev.' 1848, vol. xlviii. p. 324.

[3] Faraday in 'Philosophical Transactions,' 1845, part i. p. 171.

Chemical condensation seems to have suggested itself but little to the projectors; it is worth thinking of, as will be hereafter noticed.

This, however, could scarcely fail to have occurred to aerial projectors—that gas might be generated, as required for rising, when afloat, from materials carried up in the boat—sulphuric acid and iron to wit. This is a chemical form of the Reviewer's proposal just alluded to, and may be found among the crude notions of a correspondent[1] of M. Faujas St. Fond, and in the scheme of M. Génet.[2] That this is an impracticable shadow of a real requisite will be demonstrated in a future page.

One of the oddest notions of ballast, which might be used without being used up, is one of Dr. M'Sweeny's: 'Trained falcons may be taught to fly with a balloon, and to alight on a car at command.'[3] Surely geese would do just as well to be pitched overboard at need; a flock of Brent geese would fly close together by habit, and, being linked together, could be hauled in as required. This is at least as reasonable a use of the fowl as eating them; but I think we can do without them for either purpose. But perhaps a poor goose could not fly fast enough to keep pace with a good air-craft. Almost the only mode that has yet been in use of adjusting the height of the balloon above the ground, without loss of material, is the long rope or 'balancer' proposed by Mr. Baldwin in 1786,[4] and which, having been brought into use in modern days by Mr. Charles Green, under the name of the 'guide rope,' has been erroneously attributed to him as a discovery.[5] This contrivance, though admirable in theory, is utterly inadmissible in practice. Not much harm may be done by one aeronaut trailing his solitary line a few dozen times a year across the fields round London. But that air-craft should go dashirg about, as they will some day, in all directions, over sea and land, with a rope sweeping after them, felling and smashing every frail thing that crossed

[1] St. Fond. 'Exp.' vol. i. pp. 224, 231.
[2] Delcourt, 'Manuel,' p. 144 and part vii.
[3] M'Sweeny, 'Aer. Nav.' p. 33.
[4] Baldwin, 'Aïrop.' pp. 226, 236.
[5] Mason, 'Aeron.' pp. 16, 338.

their path below, is of course a state of things not to be dreamed of.[1] There is, however, no fear of any misunderstanding between landsmen and air-sailors on this point, for no one would think of wilfully retarding his speed through the air by holding to the earth by leading strings. Unless, perhaps, an occasional experimenter may have some crotchet about 'sailing' against a wind, and may want to try what he can do by 'kedging;'[2] but the police, no doubt, will have strict orders to take all such trespassers into custody.

Now, if the reader has followed me up and down with all these plans for rising and falling, it can scarcely have failed to occur to him that such contrivances may be very useful for balloons, but cannot be wanted in any air-craft that is provided with propulsive power. For the vessel may be provided with a special motory mechanism limited in its action to the vertical direction, and only called upon for work when it is requisite to alter the conditions of equilibrium with gravity. And farther, it is of course evident that any body that can be driven through the air horizontally, by force exerted from within itself, may be made to ascend or descend either by changing the direction in which the force is made to act, or by simply altering its effect upon the system by the movement of a tail or rudder.

[1] After writing the lines in the text, I found the following incident recorded in the 'Times' of the same day, in an account of a balloon trip made across the channel from Hastings to Neufchatel near Boulogne, by Mr. C. Green and the Duke of Brunswick on March 31, 1851:

'Two men were seen walking upon the sands (on the French shore), and as the balloon passed over them with its guide line trailing behind, one of them caught at it, and was immediately seen to be dashed violently upon the earth. The rope got under the feet of his companion, who forthwith formed a complete sommersault in the air, and was speedily placed *hors de combat*.'—*Times*, April 3, 1851.

The first man was meddling with what did not belong to him, and so perhaps it served him right; though he, no doubt thought the rope was thrown for the purpose of being caught, but it does not appear that the second touched the line at all till it felled him.

The account quaintly concludes by stating that the noble passenger found that in a balloon voyage there 'was a total absence of all *sensible* motion.'

[2] See M'Sweeny, 'Aer. Nav.' 2nd ed. p. 30.

Inventors have not neglected to devise plans of putting this principle into practice. Indeed, in the early days of ballooning, when it was the fashion for the exhibitors to carry paddles as the regular appurtenances of the car, some of them seem to have occasionally used these instruments with success for raising and lowering themselves. Lunardi, who made the first ascent with hydrogen in England, informs us that the chief aim of his experiment was to be the first 'to ascertain the practicability of rendering the balloon stationary or descending at pleasure by means of oars acting vertically;' and he was naturally very anxious to make out that he succeeded.[1]

Blanchard, too, held on pertinaciously with his wings, and says he rose and fell at will by their aid with ease and celerity, particularly on one occasion, when he must have hit the point of equilibrium between his gas and the air to a marvellous nicety.[2] He declares that his balloon, with himself and his friend in the car, alighted on the ears of some standing corn, on which they floated and glided—like the Lady Camilla, who—

> . . . vel intactæ segetis per summa volaret
> Gramina, nec teneras cursu læsisset aristas.

However, whether the ballooners found they were not equally successful, or whether the addition of oars to their furniture did not pay—not drawing more sightseers than would have come otherwise to stare at them—these implements got out of fashion; and little else has been seen in this way of late years but an occasional in-doors experiment with a model fitted with vanes. Dr. Van Hecke argued that we should find currents in all directions in the atmosphere if we only went to the right height to look for them; he proposed, therefore, to rise or sink in search of required winds by means of screw-vanes, which were to propel in a vertical direction;[3] and he is reported to have demonstrated the utility of his plan on a small scale. Mr. Green exhibited a model balloon at the Polytechnic Institution in London

[1] Lunardi, 'First Voyage,' pp. 11, 35.

[2] Blanchard, 'Third Voyage,' pp. 7, 8.

[3] Monge, 'Études,' p. 108; 'Civil Engineer's and Architect's Journal,' vol. x. p. 94.

in 1840, which was made to mount and fall in this manner by the action of oblique revolving fans.[1]

It will be needless to refer to other instances in which a portion of power has been proposed to be either borrowed from the regular propelling service of the craft, or to be set apart specially for this purpose. All the contrivers of mechanism for aerial navigation have, of course, had this in view, though they have very seldom thought of providing the power necessary to work their wafts or blowers.

The tail-steerage, however, for ascent and descent, must not pass without notice, for there would be a circumstance attending its use which has, I think, been very generally overlooked by the projectors. All the inventors of air-craft, from M. le Baron Scott to Mr. Bell, have devised rudder tails; some such implement will be seen in every print of an 'aérostat dirigeable,' or of 'locomotive balloons.'

Now, just as travelling on land may be considered as progression in one dimension, since for the most part it is confined to nearly straight lines, and as aquatic voyaging is of two, on the length and breadth of the sea-plane, so aerial navigation being the highest order of locomotion, is travelling of three dimensions, having freedom and necessities in length, breadth, and height. Road work neither requires nor admits of any steering; generally, the course is straight ahead. Sea-faring traffic must have its rudder, for horizontal variation. But in the transit of the air the course must be changeable—right, left, up, or downwards. Accordingly, if the air-craft is to be steered from behind, it must be provided either with two rudders, one like that of a ship for motion sideways, the other like a bird's tail for changing its course up and downways, or after the fashion of the after-end of a mackerel and of a whale respectively, or else with one such appendage adapted to motion in either direction. And the reader will find varieties of these two plans to his heart's content among the schemes for aerial ships.

But the adjustment is utterly inadmissible. A rudder in a ship is a very excellent and comfortable contrivance; but I do

[1] 'Mech. Mag.' vol. xxxii. p. 480; 'Mirror,' No. 999.

not think a traveller who once seated himself in an air-ship fitted with a bird-tail that really did the work expected of it, would ever venture again into such a vehicle. When a ship on the water obeys its rudder it swings round in a horizontal direction, and every object in connection with it remains in the same state of equilibrium with gravity. So with a long vessel dashing through the air, horizontally, in the direction of its length, at the word 'Up helm,' the tail being depressed, the vessel will be twisted round, not in a level plane, but in a vertical direction, its head pointing downwards and its tail upwards. And this not only to the grievous discomfort of the passengers, but to their imminent danger, for every moveable thing on board would slide down to the lowermost end, and a greater weight being thrown there the balance of the whole system would be disturbed; the upward end of the gas-vessel being relieved of load would tilt up farther, and the lower end would be dragged down farther and farther, till everything was either pitched out or huddled into a heap at one end of the vessel. It is quite evident that these changes must ensue on any attempt to make the air-craft rise and fall like a bird. It is not an animal, but a vehicle, and must not, therefore, be expected to soar and plunge as if it were a mere fowl. Mount and sink it must, but in doing so it must maintain its true level position. Therefore, except for very slight and gradual ascents or descents, the use of a tail or plane at one end of the apparatus, whether gas or man-vessel, moving about a horizontal axis, is inadmissible.

Very few of the inventors seem to have perceived this. Some indeed, and among them M. Monge,[1] have proposed to alter the elevation of the air-craft by changing the direction of its head, while in motion, by means of a shifting weight, which by its position with respect to the length of the vessel, would adjust the dip of the head or stern, and so direct its course.

The difficulty has been solved, however, in the proper manner by Mr. Sadd of Wandsworth, whose system of twin gas-vessels I have before discussed.[2] He uses a pair of equal horizontal surfaces at opposite ends of his apparatus, fore and aft. The

[1] Monge, 'Études,' pp. 110, 141. [2] Vide p. 46.

result of this will be at once evident. These two planes being moved parallel to each other, receive of course, when the vessel is horizontally propelled, an equal resistance from the air, and being on opposite sides of, and equi-distant from, the centre of gravity, about which the whole body is virtually balanced, they produce an equal pressure in the same direction on both ends of the vessel. No twisting action at all results, but a direct upward or downward force acting on the whole vessel, whose head is still pointing in the same direction as before the planes were shifted. The motion thus obtained is of course deducted from the propelling effect of the motive power, a certain amount of its force being in fact resolved in another direction, which will be upward or downward, according as the lower or upper surfaces of the planes are directed forwards. These planes form in fact a pair of kites; they are not rudders at all.

I had been surprised at not having found this requisite acknowledged and provided for in the book-plans that I had met with, and was much delighted when Mr. Sadd showed me his contrivance in his little shop. He said he could not get on at all till he hit upon this invention. The only objection to this device is that it is unnecessarily complex; and that if the two were not kept perfectly parallel, they would not act alike, and a twisting effect would result; and if one of them got out of order, the other when moved would act as a tail, and tilt the head up or down. The necessity of this double arrangement seems to have been imposed upon its ingenious author by the very arrangement of his twin system of gas vessels with the boat between them.

Now rising and falling in the air is possible by some of the methods I have mentioned without loss of gas or ballast. This has been proved. But is this enough? Simply to rise and fall, to clear a mountain or a steeple when seen at a sufficient distance ahead, adequate force may no doubt be obtained by borrowing from the propulsive power. But there are other conditions to be provided for. A mountain on a dark night may not become visible till the vessel is close upon it, and to avoid it, it may be necessary to mount rapidly.[1] A sudden addition of a great

[1] Perhaps some future Bridgewater treatise may show that the whiteness of snow is a special dispensation for the safety of aerial travellers—

weight to the air-craft would be a serious difficulty, and unless there were other means for meeting it than that of taxing the forces required for direct speed, considerable inconvenience might ensue. Now a fall of rain brings with it this very condition, suddenly loading the gas-vessel with some hundreds of pounds' weight in water, additional to the load with which the craft was charged a few minutes before, and the condensation of moisture on the extensive surface of the envelope at night may equally, but more gradually, subtract from the floating power of the vessel.[1] Atmospheric moisture is, indeed, probably the most serious enemy the aerial navigator will have to encounter. Its attacks, therefore, must be provided against. It would be uttering a rash judgment to assert that ballast must not be carried, even as the safeguard against contingencies of this kind.

Ballast may be carried perhaps for these and other emergencies. But the waste of gas is utterly inadmissible, except in case of catastrophe—such as a fracture of a main suspension line, or the fall overboard of a heavy weight, or even of a man,—for there must be accidents sometimes in this as in other human employments, though the travelling of the air will be incomparably the safest mode of transit we shall use. Then, and then only, must the precious boon be sacrificed. Ballast can be had anywhere by stooping to a sea or river, in any quantity. Great charges of hydrogen will be in readiness only at the ports or stations, which certainly will not be few or far between. But 'waste not, want not' must be the motto of the captain of the gas-vessel.

It will, however, be most highly desirable for the sake of ensuring uniformity in the speed of the craft, that the driving-power should not be liable to be unnecessarily taxed for the purpose of raising or lowering the vessel in the air. We may then state another of the conditions of our art, thus: *The air-craft must be provided with the means of rising and falling in the air without any unnecessary expenditure of gas, of ballast, or of propelling power.*

rendering the only obstacles they can meet with at great heights visible to them in darkness.

[1] Mason, 'Aeron.' pp. 14, 336.

CHAPTER VII.

THE GAS-VESSEL—THE QUESTION OF SHAPE.

THE introduction of the propelling force into the consideration of the last condition might lead on naturally to the discussion of this important point in farther detail; but I shall prefer first to continue the discussion of those parts of my subject which pertain especially to the equilibrium of the gas-vessel.

Now I have had frequent occasion to allude to the form of the gas-vessel as being one of the most important elements in the calculations respecting the practice of aerial navigation. It was evident to the earliest speculators and experimenters on balloon propulsion, that the spherical form is a very unfavourable one for rapid motion through the air. It was evident, too, that if a given amount of gas was contained in a globe which it just filled, it would, on any endeavour to move it through the air, suffer a greater resistance from that fluid than if it were packed in an elongated vessel. The first attempt to take advantage of this principle seems to have been made by the brothers Robert with the assistance of the Duc de Chartres (or *vice versâ*, according as the reader may consider skill or capital the worthier agent in any undertaking) in 1784. The gas-vessel in this case was of the form of a cylinder with hemispherical ends, being fifty-five and a half feet in length, and thirty-four in diameter. This was the vessel with a swimming bladder before spoken of.[1] In this case, then, the proportion of the shorter axis to the greater was that of $\frac{1}{1 \cdot 62}$. No improvement upon this has been made in practice yet, for the very good reason that were ever so good a form con-

[1] P. 62 *supra*.

structed, the benefit of it would not have been available, by reason of the vicious modes of suspension of the man-vessel, and of application of the propelling force that have generally been adopted. It would be foreign to my purpose to notice all the different forms that have been proposed from time to time for enabling the gas-vessel to cleave its way through the air. It will be sufficient to mention a few of the most remarkable instances, to the end of ascertaining the position in which the question of form stands at the present time. Scott proposed to imitate the form of a fish, making the proportion of the greatest depth to the length about $\frac{1}{3}$. He says that this is the form of the swiftest fishes,[1] which is certainly an error: the length is considerably greater. He proposed also to flatten the vessel laterally in imitation of these animals. However, the drawings which he gives of his projected craft are not the least like any known fish, but exactly resemble a creature not known in his days—a prize pig. De Lennox's aerial eagle, torn to pieces by the mob on August 17, 1834,[2] and which managed apparently, Phœnix-like, to come to life again in London in July in the following year, was 160 feet long, 50 feet high, and 40 feet wide,[3] having, therefore, the ratio, mean thickness$\div$length$=$ about $\frac{1}{3{\cdot}5}$.

As instances of other forms which have been proposed for the purpose of eluding the resistance of the air, the following may be mentioned. Mr. Partridge's conception with a Greek name,[4] which has been alluded to before, was to have been a compressed prolate spheroid, 'whose respective diameters bear proportion to the integers 7, 4, and 2.' So that taking the mean of the two less numbers, as the smaller diameter, its ratio to the major axis would be $\frac{1}{2{\cdot}4}$.

Mr. Sanson's 'lenticular ellipsoid' is one of the most curious devices of this kind. Its greatest length, depth, and thickness are to be, one to the other, as 20, 12, 5;[5] nearly the same proportions as those of the last-mentioned proposal. Each schemer

[1] Scott, 'Aérost. dirig.' p. 23.
[2] Delcourt, 'Manuel,' p. 139.
[3] 'Mech. Mag.' vol. xxiii. p. 290.
[4] 'Mech. Mag.' No. 1032, p. 396.
[5] Sanson, 'Explic. Nav. Aer.' p. 5.

selects a form that suits his taste without assigning any reason for the selection. Mr. Bell in his specification of his patent, before mentioned, claims 'the forming of the buoyant part of balloon motor machines of an elongated form,' and gives a drawing of what he believes to be the best such form. It is such a shape as would be generated by cutting two Gothic windows in half horizontally, clapping the pointed parts together, base to base, and pinning them about an axis passing lengthways through the points. He, however, omits to state the grounds of his preference for this form.

But the views of M. Marcy Monge as to the proper form of a gas-vessel must not be passed by in this review, as affording a most remarkable instance of oversight in the application of simple geometrical principles. He points out the fact which, if not obvious at once, will become evident to anyone on experiment, that no surface of double curvature (i.e. no surface that may not be generated by the motion of a straight line) can be compressed without being thrown into folds.[1] He adds that folds and wrinkles are very injurious to gas-envelopes, as tending to wear them out. Farther, all the forms usually adopted and proposed for the gas-vessels of air-craft—such as balloons, eggoons, fishoons, cylinders terminated with hemispheres, and prolate spheroids—are liable to this result. He therefore rejects them all as vicious. M. Monge then starts with the axiom that it is necessary that in all air-craft the gas-vessel should be kept tense by the pressure of the gas within, for the purpose of enabling it to withstand the resistance of the air to its bows. Now this, firstly, is not necessary, for the desired object may be more effectually attained by other means. He likewise considers that it is requisite that the envelope must be made of material possessing some degree of stiffness; which, secondly, is unnecessary. He believes, too, that this internal pressure will be most easily ensured by applying compression from without to the gas-vessel, so that when it should be tending to flaccidity, by reason of loss of gas, its surface may be tightened by squeezing in its sides. Now, if the envelope is to be made of any material that is

[1] Monge, 'Études,' pp. 42, 56.

not perfectly flexible, like woven cloth, and if it is to be compressed, it must be of such form that when pinched together it will not be thrown into folds, and so be rendered liable to crack. Now, cylinders and cones are 'developable' surfaces (i.e. surfaces generated by the motion of straight lines), and figures of this kind have the property of submitting to change of shape without their surface becoming wrinkled. A cone, too, is a form well adapted for cleaving the air, and a cylinder capped at each end by cones is better still; and it is, he says, very nearly as good a figure for rapid motion through an elastic fluid as a long spheroid or fish shape (of which latter point, by the way, proof is wanting). A cone may be bent without wrinkling, so may a cylinder; therefore, cylinder and cone together unite all the requisites for a gas-vessel—beak to cleave the air, length to slip through it, tail to fill the void and receive pressure behind, and freedom from liability to fold. M. Monge takes great credit to himself for this happy device, on the excellence and necessity of which he insists throughout his book, greatly extolling his 'aérostat developpable,' which he confidently asserts to be the only form of gas-vessel admissible in the aerial navigation of the future.

Now, that so singular an oversight as is involved in this conception should lie at the foundation of a laborious and really valuable work, is not a little curious.[1] His proposition is undoubtedly true of the cone and of the cylinder, separately, but not of the two when united by their edges into one figure. A cylinder of course may be flattened, and when partially compressed will still stand steadily upon a level surface on its end, which was circular before its shape was altered; and even if it be squeezed quite flat, so as to bring its two sides together, the end, now become a straight line, will fit quite truly upon a plane surface. But that this is not the case with a cone is well known to everyone who has ever had occasion to use a paper filter. It will be at once evident to anyone who will make a cone by cutting out a circular piece of paper, doubling it across on one

[1] Another instance of error in the same book, arising from carelessness or insufficient knowledge of the elementary facts of the science which the author was treating, will be noticed hereafter.

diameter, so as to form the figure of a semi-circle, and then doubling it again, so as to bring the opposite angles of the semi-circle together. The paper is now folded into four sectors, each of which is the fourth part of the area of a circle. If now the folded paper be evenly opened out, by keeping three of the thicknesses of the paper together, and drawing them away from the fourth, a cone will be produced which will stand upon a table upon its base, the edge of the paper touching the surface all round. Its base may of course be applied in the same way to the circular base of a cylinder of the same diameter, and their edges will be in contact at every point. If now, while the cone be standing on its base, it be compressed so as to bring its sides nearer to each other, the edges of its base will leave the table, and the figure will only touch the flat surface exactly at two opposite points. The more the cone is flattened, the farther the rest of its base-edge will be withdrawn from the level of the table. And when it is flattened to its original shape its lower edge will form a circular quadrant, to which a line drawn on the table will be a tangent. Just so it will be when the cone is applied to the cylinder; the figure will be perfect so long as it is not compressed at all, but as soon as it is the least flattened by squeezing sideways, the edges of the cone-base will start away from the edge of the base of the cylinder, the separation commencing at two points at the extremities of a diameter at right angles to the plane in which the compression is applied—a result which, it is needless to add, would be quite fatal to the gas-vessel. If the joints were so strongly made between the cones and the cylinder that they could not be rent apart in this way, the material would yield in some other place, either by tearing or running into folds. In fact, it may be said that the whole tendency to wrinkling, which is distributed over the whole surface of the gently-curved spheroid, is here gathered together into the one line of junction of the cone and cylinder; so that the 'aérostat developpable' is not only not a good form for the purpose for which it is designed, but positively the worst that could be contrived for it.

Whether the cone-capped cylinder is a good shape for evading the resistance of the air, independently of M. Monge's crotchet

of compressors, is another question which experiment alone, at present wanting, can determine. There is every reason for believing that it would be far inferior to an elongated spheroid of equal minor diameter and length, or of equal minor diameter and equal capacity. There is no instance in nature of such a form being applied to the purpose sought in this case. It is an ugly shape, would be very liable to injury at the junction of the two figures, and its only recommendation is the facility with which it can be constructed by rolling up plane surfaces, without any 'cutting to waste,' as is generally necessary in making spheroidal forms out of flat materials.

Sir George Cayley proposed, in 1816,[1] to give to the gas-vessel the form of a woodcock's body, of which the thickness is to its length as $\frac{1}{3\cdot5}$, selecting this bird on account of the long flights which it makes at great speed. He remarks that not even the theoretical skill of Newton can point out to us the best form for eluding the resistance of the air; and, observing that the shape of the after end, or tail, is of fully as great importance as that of the head, he subsequently (1837) concludes that in a first attempt it would be sufficient to make the gas-vessel a prolate spheroid,[2] or elongated egg, taking $\frac{1}{3\cdot5}$ as the proportion of the minor to the major axis. He farther narrates an experiment which he made for the purpose of ascertaining in what degree such an elongation of form diminishes the resistance offered by the air to a solid moving through it. Since this is the only experiment on record, so far as I am aware, tending to show what is the real amount of opposition which the air is likely to present to air-craft, I here subjoin his words on this matter.

'Mr. Robins found that a sphere only meets with about one-third of the resistance of its great circle, being as 1 to 2·7; others have found it still less, but experiments are scarce on this subject. With a view to the present enquiry, I made a light case of papers, glued together over a true spheroidal mould, 18

[1] 'Phil. Mag.' vol. xlvii. p. 324 and Part IV.

[2] 'Mech. Mag.' vol. xxvi. p. 420; 'Phil. Mag.' vol. l. p. 35 and Part I.

inches long by 6 in diameter, and loaded it so as to fall through the air in the line of its longer axis. A circle of 6 inches diameter was then loaded till it fell with equal velocity, keeping perpendicular to the line of its fall; the weight required to drag the flat circle with equal speed, side by side, through a fall 30 feet, was 4·8 greater than that of the spheroid (of course the whole weight of each apparatus was thus the measure of the resistance). The additional weights, used to bring the circle to an equal velocity with the spheroid, were so arranged within similar cases, as to give equal resistance.'[1] The author concludes that the gas-vessel which he proposed, having a length $3\frac{1}{2}$ times greater than its greatest breadth, whereas in the experimental spheroid the proportion was 3 to 1, the resistance to the former might be assumed to be not greater than a sixth part of that which would oppose a circular plane of diameter equal to its minor axis.

I have before stated (p. 52) that though it was very soon evident that the figure of the gas-vessel must be a long one, it was very generally believed that it must not be very long. It has been believed that our approach towards the fulfilment of one of the requisites of aerial navigation—the eluding the resistance of the air by giving length to the gas-vessel—was limited by other conditions, which were equally essential, and which seemed to demand an opposite arrangement for their satisfaction. Mensnier, indeed, in considering what the figure of the gas-vessel should be, concluded that its greater axis must not be more than three times the length of the lesser. I shall have again to recur to this point, and to the reasons on which he pronounced this canon, of which the correctness seems to have been assumed by nearly all those who have dealt with the subject. Even if the projectors have not been aware of Mensnier's dogma, they seem to have met with or to have imagined difficulties, which have led them to the same opinion. M. Monge, indeed, refers to Mensnier as an authority not to be disputed in this matter, and acknowledges his adherence to the conclusion.[2]

Now, if this were true, aerial navigation would, I believe, be

[1] 'Mech. Mag.' vol. xxvi. p. 423.
[2] Monge, 'Études,' pp. 48, 119, 121.

hopeless. We never should be able to attain any speed through the air with such miserable tubs as vessels built on these proportions would be. I do not believe there is any such perversity in nature as this antagonism of conditions would imply, established for the purpose of preventing us from asserting our dominion over the ocean of the atmosphere. There are difficulties interposed, no doubt, to start up in our path at every step, but not to thwart us, only to stimulate us to exertion for their vanquishment.

It is absolutely necessary that the gas-vessel must be long and thin, of some fish-like form. There may be difficulties in practically adopting such shapes to the work that air-craft has to do; but there are no impossibilities, and the mere difficulties must vanish before the necessity of our success. This seems to have been perceived by a humble philosopher in a little country village in France, M. Jullien, the working watchmaker, whom I have before had occasion to mention.

An experiment was publicly made in the Hippodrome, at Paris, on November 6, 1850, of which an account may be found in 'La Presse' of the following day, and in 'L'Illustration' of November 15–22. The latter journal gives a drawing of the apparatus with which this exhibition was made. It was a fish-shaped gas-vessel, with a clockwork mechanism suspended to it, by which were driven a pair of screw propellers attached to the side of the fish near the head. In this sketch the long axis of the vessel is made $7\frac{5}{8}$ inches long, and the greatest thickness $\frac{7}{8}$ inch. The dimensions are not stated, but the drawing is probably not far from the true proportion; the ratio of the greatest thickness, then, to the length was $\frac{1}{7 \cdot 8}$. Now this is something like a shape, and the little air-craft is stated to have flown successfully against the wind. How did its contriver arrive at this result? An account of a visit to him will inform us, and, as it gives a good example of the industry of retired genius, I shall quote it. The writer appears to be a literary gentleman with a taste for aeronautics, an ardent belief that it is our destiny to enjoy the use of the art, and, as appears from this extract, a keen perception of worth in a fellow-worker. I translate his

words[1] from his lively, popular brochure on 'Balloons,' lately published :—

'We have been to see M. Jullien at the little village in which he lives. We found him there in a small shop rather less than a porter's lodge; he was busied in setting to rights the wooden clocks and huge silver watches of the inhabitants of Villejuif. He took us up into a little room about six feet square, where he showed us the principle forms of screw-propellers which he had tried before he determined to employ the two vanes which he has now in use. He told us how he had been led, by observing the wings of insects, to round the angles of his vanes, and to give them greater stiffness towards their point of attachment; how he had made trial of his mechanism by making little cars, to which were fixed the propellers that he wished to test, run along an iron wire stretched up in the fields. Passing then to the form to be given to the gas-vessel, he showed us *little spindles of wood, of which he had studied the movements in water.* Finally, he explained to us how he had been led to fix the two rudders at the extremity of his apparatus. The mayor of the village, an intelligent and good man, told us the tale of the life of perseverance and of disappointments of all sorts, which the poor inventor had had to lead before he had arrived at any result. The winter of 1847, the years 1848 and 1849, the cholera, want of work, the death of his wife, did not prevent him from steadily pursuing his idea, refusing all assistance which the warden of the parish offered him from the funds devoted to the services of charity.'

This is a hero indeed. All honour to M. Turgan for his good words for M. Jullien.

Now this poor mechanic has done more towards settling the question of aerial navigation than all the learned academies and encyclopædists in Europe have done, either in favouring its struggles or in endeavouring to prove its impossibility. He simply and faithfully set to work to ask the best questions he could of Nature, nothing doubting that she would render him true answer.

[1] Turgan, 'Ballons,' p. 200.

However, though M. Jullien has clearly seen what the true sort of shape for an air-craft must be, and though he has evidently set to work in the right way to test his conceptions by experiment, he has not shown how the proper form is to be adapted to a gas-vessel of navigable dimensions; at least, he is not stated to have done so in the accounts of his experiments which I have seen. What he has shown is that he knew what the shape ought to be, and that he had found this out, while inventors richer and more favoured than himself had been wasting time and money in building useless, shapeless toys.

The great question involved in this problem of the best shape of the gas-vessel, and of the boat too—for in a working air-craft that will be a very important point—is, what is the resistance of the air to bodies of different forms? What is the form to which, at a given velocity, the resistance of the air is least? Now there is positively no answer at all to these questions, yet to be given. The question has never yet been asked of Nature. Few experiments would yield more interesting results, and few could be made more easily and simply than a series undertaken for the purpose of ascertaining these points. It has never been done, and wise men have been contented to suppose that the resistance of the air is so great as to render vain all attempts to overcome it. The only facts bearing on this subject that we possess, so far as I am aware, are the results of some experiments made by Mr. Rouse, and others by Mr Robins and by Dr. Hutton. The first-mentioned results are given in a table by Mr. Smeaton, in a paper of his entitled 'An Experimental Enquiry into the Natural Powers of Wind and Water to turn Mills and other Machines.'[1] No statement is given as to the mode by which Mr. Rouse's measures of force were obtained; but, it being understood that the authority given for them was that of a careful experimenter, they have always been accepted as correct. They are of no use in attempting to estimate what resistance would be offered by the air to the progress of air-craft. The numbers refer only to the resistance, estimated in pounds, to thin planes moving in directions at right angles to their surfaces,

[1] 'Philosophical Transactions,' vol. li. part I. 1759, p. 165.

so as to be constantly in parallel positions. They are utterly useless towards giving any notion of what amount of obstacle the air presents to aerial navigation; though they are very useful and very promising in determining what degree of help it will give us in this direction. For it will be to such flat surfaces, in many cases, that we shall trust, as wings, to give us the resistance which will be absolutely necessary for propulsion. I shall not trouble the reader with the numbers, which Smeaton gives in detail, for the Table is quoted by almost every writer on aeronautics, and so has been very often reprinted.

The next experiments at all connected with this subject are those of Robins, recorded in his work on Gunnery.[1] His experiments were all made with globes for a purpose, if not very different in theory, we will hope the very reverse in practice, of that for which we require information. He desired to know what amount of resistance was offered by the air to the motion of spherical shot, of which the very mission is the destruction of life and produce, and of which the use implies the denial by men of their brotherhood and the defiance of the law of love. Now the chief aim and certain result of the traffic of the air—of the true Pacific Ocean—is the bringing together of all men and of all nations into one bond of friendship. It is therefore very fitting and appropriate that these experiments of Robins's for the improvement of winged murder should have no bearing whatever on our question, either towards showing the facilities or the difficulties of our art. We have no use for globular figures in aeronautics, either for taking or escaping resistance; so we need not go to the cannon-balls for information. He gave us, however, one hint, which it is for us to improve, namely, that the resistance of the air may be evaded to a certain extent. He found that spheres met with only one half of the resistance opposed to circular planes of equal diameter; encouraging so far as it goes.

The next, and I believe the last, contributions on this head are those of Dr. Hutton, who performed his experiments with the same instrument with which Mr. Robins worked, which he

[1] Robins's 'New Principles of Gunnery,' revised by Dr. Hutton, London,' 1805, p. 200.

calls a 'whirling machine.'[1] His experiments were not made with so purely destructive a view as those of his predecessor, and embraced a few other forms besides spheres. He desired to extend a little farther our knowledge of the behaviour of the air towards bodies moving through it. His experiments were made on hemispheres with the round and with the flat side foremost, on a flat disc, on a short cylinder, and on a cone with base and with point foremost.

Robins had proved, what dynamical theory had indicated, that with small spheres the resistance was proportional to the square of the velocity. Hutton confirmed this result, and farther came to these conclusions:—That the resistance is proportional to the surface with bodies of similar shape, but, when they are very large, that it increases a little more rapidly; that the round and sharp ends of certain solids suffer less resistance than do the flat sides; that when the hinder ends are of different forms the resistances are different, 'owing probably to the different pressure of the air on the after-parts.' He gives us no information whatever on the amount of resistance experienced by bodies of a considerably elongated form. Indeed with the 'whirling machine,' as I shall afterwards have occasion to notice, he could not have obtained any useful results in this direction if he had been inclined to try. These experiments were made long after the invention of balloons, when aerial navigation must have been more or less canvassed within the range of his communications; but in the altitude in which scientific men generally were inclined to regard this subject, it is scarcely likely that it should have occurred to him to connect it with his enquiries.

However, notwithstanding the promise given by Robins's results, of farther possible diminution of the resistance, orthodox science has been willing to assume that the opposition of the air is too great to be overcome. Now, if it were not true, as it is, that the greater the resistance of the air the more chance we have of success in propulsion, a sufficient answer might be at once given to this objection, thus:—All these experiments have been at the surface of the earth, where the resistance of the atmosphere

[1] Hutton, 'Philosophical Tracts,' vol. iii. p. 164.

is greatest; but air-sailors may, by choosing the level at which they will navigate, reduce the resistance to their progress to any fraction of what it would be at the surface. Experiments, therefore, made on the dense air at the surface cannot, it might be said, prove anything against the possibility of actions concerned with the rarer fluid of the upper regions.

And so matters have stood: we have yet learned nothing more about the resistance of the air. Indeed, though people were fully impressed with its magnitude when they thought of balloon propulsion, they were almost inclined to ignore its existence when it interfered with their own pursuits. It was supposed by railway engineers that the resistance to trains in motion was independent of their speed; that is to say, that the resistance of the air to their motion was nothing. But, in 1838, Dr. Lardner conducted a course of experiments upon trains allowed to run down railways upon inclined planes. 'From such experiments it followed,' says this author, 'contrary to all that had been previously supposed, that the amount of resistance to railway-trains had a dependence on the speed; that this dependence was of great practical importance, the resistance being subject to very considerable variation at different speeds; and that this source of resistance arises from the atmosphere which the train encounters. This was rendered obvious by the different amount of resistance to the motion of a train of coaches, and to that of a train of low waggons of equal weight.'[1] Yet, notwithstanding the hint thus obtained, no experiments have been made to ascertain what is the actual amount of this resistance of the air; so that this hint has led us to no new information on this subject. And not only have railway engineers not provided themselves with any such data as would be of use to aerial engineers as well as to themselves, but they have gone on pretty nearly as if they had never learned that this great force was ever active in retarding their speed, and wasting their power. And not only have they neglected to combat this by providing suitable bows and sterns to the trains for diminishing this obstacle[2] to their speed, and the

[1] Lardner, 'The Steam Engine explained and illustrated,' 7th ed. London, 1840, p. 410.

[2] There can be no doubt that if the fore part of the train were covered

expenditure of their coke, but they have proceeded in their calculations, and stated their results as to the amount of work done by the train-engines, just as if this condition was unknown. For instance, in the book just quoted, a few pages after that in which this fact is stated, it is calculated that a train is moved along the road by a force of about 23·4 pounds per ton of the gross load.[1]

with a shield, or cut-air, which might be glazed so as to enable the engine drivers to see, if the spaces between the carriages were closed up, and if the train were provided with a tail, the resistance of the air to their passage, and the power necessary to produce a given speed, would be much diminished. It is probable that barometers hung one in front of the foremost, and another behind the last carriage of one of our express trains, would indicate a perceptible difference in the pressures of the atmosphere at the two points, the latter being probably below, and the former above that due to the actual atmospheric pressure. The experiment could be easily tried; and would be worth trying.

[1] Lardner, 'Steam Engine,' p. 414. It is stated that a train weighing 80 tons is propelled, at about 31 miles per hour, by a force which is shown to be equal to about 1875 pounds exerted constantly in the direction of motion. Now supposing that the only resistance the train meets with from the air is that upon the front surface of the foremost carriage, and supposing that this surface amounts to 50 square feet, which will not be far above the truth (if the face of the carriage were 7 feet on each side, it would have of course an area of 49 square feet), and assuming the resistance of the air to be correctly stated in Roase's table (where for 30 miles per hour it is stated to be 4·429, and for 35 miles 6·027 pounds per square foot), we may take the resistance due to 30·93 miles per hour (the mean speed of the experiments to which the statement refers) to be 4·5 pounds per square foot. The whole resistance, then, on the front face of the fore carriage would be $4{\cdot}5 \times 50 = 225$ pounds. Now $\frac{225}{1875} = {\cdot}12$; more than a tenth of the whole available force, consumed in striving against the resistance of the air. Now even if this were all, it would be well worth diminishing: but it is no doubt far greater, for every carriage-front must add something to the resistance; though, of course, not so much as if it were not shielded by the vehicle before it. A certain portion of the atmosphere between the carriages must, if they are close together, be carried forward with them in a state of rest; but that this quiescence is by no means perfect will be readily conceived by any railway traveller who has sat near the open window of a train-carriage, and facing the engine. If there is a considerable distance between the back of one coach and the next, as when a long train is interrupted by some low trucks, the resistance of the air to the front of the coach that comes next

It having been shown just before that there was one large element in the resistance which the force had to overcome which is quite independent of the load, and that, therefore, the force exerted cannot be measured at all by the load of the train.

More recently Mr. Scott Russell read a paper to the British Association for the Advancement of Science[1] 'On the Resistance of the Air to Railway-Trains at High Velocities.' This gentleman takes the resistance of the air into consideration as one of the forces to be overcome by the power of the engine; that is to say, he mentions it and acknowledges its importance; but in his estimate of the force exerted by the engine, he ignores it altogether, by expressing the work of the engine in terms of the weight of the load. This gentleman contributes nothing to our knowledge of what the resistance of the air is; but assumes it, according to the regular dynamical theory, as proportional to the area of the surface resisted, to the density of the air, and to the square of the velocity of the train, taken conjointly. It is remarkable that the experiments in which he is understood to have been engaged, on the resistance of water to ships, had not led him to speculate, at least, on the diminution which might be effected in the resistance of the air to railway-trains by modifying their form.

However, though nothing is known as to the extent to which this important element of aerial navigation may be controlled, we might hope to get some hints from our somewhat fuller information as to the resistance of water to bodies passing through it. Our knowledge of this branch of practical dynamics, however, is far from perfect; but so far as they go they tend to prove that the resistance of the liquid (water) to bodies passing through it is much diminished by increasing their length. An elaborate series of experiments on this head was made by the French Academicians. Colonel Beaufay devoted a great part of his life to a course of experiments on the resistance of water to wooden figures of various forms entirely immersed in the liquid. His results are minutely recorded in a magnificent volume printed

behind the gap, must be nearly as great as that encountered by the first carriage.

[1] 'Report of Proceedings of Brit. Assoc.' for 1846, Part II. p. 109.

after his death by his son. More recently Mr. Scott Russell undertook to conduct some experiments under the auspices of the British Association for the Advancement of Science, for the purpose of determining the best forms for ships. He remarks:[1]— 'In nothing does calculation more completely fail than in the attempt to determine beforehand the speed of a ship constructed on given lines, or to show how a form may be so altered as to render it faster than before.' He demonstrated that for each velocity, there is a corresponding form and dimension peculiarly suited to receive such speed from the exertion of a given amount of force. This is a most important fact, and will no doubt one day be ascertained to be equally true of the air, and will be recognised as bearing most closely on the various requirements of the traffic of the air. The building of gas-vessels will be a distinct art, in which as much science and skill will have to be invested as in the cotton manufacture, or the construction of railway-engines. But the perfection of the art will not be left to 'free' competition, and the private enterprise of individuals, or of companies, or of congregations devout in the worship of mammon, but will be secured by the co-operation, for the common benefit, of men, peoples, and governments. But co-operation on a smaller scale will make the beginning which experiments hereafter will develop to maturity.

A most disheartening statement occurs in one of Mr. Scott Russell's brief notices on this subject.[2] It is to the effect that Colonel Beaufay had made a series of experiments at a cost of 30,000*l.*, but that these are of little value, as the forms of which he made use were not such as are required for ships. Thus, in one short sentence, is dismissed as worthless an amount of careful and persevering labour, which to quiet, easy-going people it is almost awful to contemplate. 'Then I looked on all the works that my hands had wrought, and on the labour that I had laboured to do: and behold all was vanity and vexation of spirit, and there was no profit under the sun.'[3]

Now, there is another remarkable point about these liquid-resistance experiments. Mr. Scott Russell's results, which no

[1] 'Brit. Assoc. Report,' meeting of 1843, p. 112.
[2] 'Brit. Assoc. Rep.
[3] 'Ecclesiastes,' c. ii. v. 11.

doubt are not all 'vanity and vexation of spirit,' are not published, or if published, are nowhere to be found. On the very day on which I was writing these pages about fluid-resistance, and had come to this very point, I find my own disappointment on this matter echoed by two other persons, thus:

'A correspondent asks "Where he can find an account of Mr. Scott Russell's wave line theory?" We believe that Mr. Russell's views on ship-building have not been given to the public in any work, or in the transactions of any society. At least we have been unsuccessful in our search.'[1]

So not only do we know nothing about the extent to which the resistance of the air may be eluded by appropriate forms, but we know very little about the behaviour of water as regards the same conditions. So that we cannot even get the full benefit which we might expect from analogies between the fluid air and the liquid, with which we are more intimately acquainted. Thus much, however, is certain, that in both cases the resistance due to a given area of cross section may be immensely diminished by the use of appropriate forms. The only doubt is, as to the limits beyond which this diminution may be carried.

It must be borne in mind that the kind of resistance which ships have to encounter is very different from that which will attend the movement of air-craft. In the first place, the ships of the present day are only partly immersed in the liquid. Floating as they do on the surface of water, they have two resistances to face; that of the water to their lower parts, and that of the air to the part above the water-line. Again, the amount of resistance offered by the water to vessels at sea is continually varying, by reason of the irregularities of the waves and of the pitching and rolling of the vessel, by reason of which the form of the part immersed is ever changing. Secondly, the kind of form best suited for sailing-vessels must be a mean of various shapes, each best adapted to sail under a wind meeting it at a different angle; and this mean is probably very different from the lines on which the fleetest steamer would be built. Farther, it is commonly supposed that there is a limit to the length, and there-

[1] 'Mech. Mag.' vol. liv p. 268 (No. 1443, April 5, 1851).

fore to the swiftness, of all steamships imposed by the nature of the materials used, that is, by the liability of a long narrow vessel to 'break its back' if its length is unequally supported on the waves. This, as I shall hereafter endeavour to show, is not the case with gas-vessels for aerial navigation. An air-craft is neither a bird, a fish, nor a ship; its nearest relative is an arrow. If any man has ascertained by careful experiment the best forms for arrows, he has given the best hints we can yet find for the shapes of gas-vessels; but I have not met with any account of such experiments.

The results of Colonel Beaufoy come nearest in analogy to the facts which we require, as they were obtained with bodies immersed entirely in a single 'medium.' They will be very interesting some day, as points of comparison with the future results of similar experiments on bodies moving in the air. And though they may not be so useful as he desired, for the purpose of ship-builders, who are contented to see their handiwork float duck-like on the surface, they may be appreciated by the mariners of the future, who will convey their cargoes within the sea while the consumers of the produce are dashing through the air.

M. Jullien, the French philosopher, whom I mentioned a few pages back, having no access to the records of the researches of learned Frenchmen or Englishmen, rightly took the best course that was open to him, and made experiments for himself. He no doubt considered that if the water did not give him exactly the facts he required, it would at least give him hints that would not lead him far wrong if he followed them.

However, to deduce exact conclusions as to the air, a highly elastic fluid, from the behaviour of a liquid so comparatively sluggish as water, is clearly impossible. Their tendencies as to resistance must be generally the same, but their habitudes in detail, which will govern the finer varieties in form, must be dissimilar. This is a matter yet to be enquired into, that, as ever, we may conquer nature by obeying its laws.

Here, then, is another of our requisites:—*The vessels of air-craft must be of an elongated form, to enable them, by cleaving the air, and eluding its resistance, to receive the highest velocity attainable by the exertion of a given amount of power.*

CHAPTER VIII.

THE GAS-VESSEL—THE QUESTION OF MATERIAL.

THE consideration of the form of the gas-vessel leads us very naturally to that of its material. I have already had occasion to allude to some materials that have been proposed for the construction of this part of the apparatus.[1] The material almost always used for the construction of balloons (the only kind of aerial gas-vessels at present in use) is varnished cloth. The woven texture is generally of silk; cotton has frequently been used. The first balloon of the Montgolfiers, raised by rarefied air, was made of linen and paper (*toile doublée de papiér*);[2] and since perfect impermeability was not necessary when so cheap a substance as common air was the agent, no great variation from these materials was introduced in subsequent fire-balloons. They have usually been made of cotton-cloth, sometimes impregnated with alum, to make them flame-proof.

Silk varnished with caoutchouc was already an article of commerce in Paris when the experiment of the Montgolfiers was announced as having taken place at Annonay. It was immemediately pressed into the new service to assist hydrogen in doing its lifting work.[3] It was found so effectual for the purpose of confining the gas, and was so much lighter than any other material that could be suggested as equally air-tight, that with but little change it has kept its ground as the best material for balloons. The chief improvement has been in the modes of making and probably of applying the varnish. India-rubber, notwithstanding its elasticity and imperviousness, has been found not to be the best material for the purpose. Mr. Charles Green,

[1] See p. 63, above. [2] St. Fond, 'Exp.' p. 3. [3] *Ibid.*, p. 8.

who invented the process of uniting two webs of cloth, surface to surface, by caoutchouc cement, said, in his evidence before the Court of Common Pleas, in the case of *Macintosh* v. *Everington*,[1] that he found caoutchouc useless as a varnish for balloons; but that he made the upper and lower parts of his gas-vessels of silk doubled by uniting the textures with india-rubber dissolved in oil of turpentine.

Linseed-oil, as is well known, undergoes by 'boiling' a change which is not, I believe, thoroughly explained by chemists. By this change it has acquired the property of 'drying,'[2] when ex-

[1] 'Mech. Mag.', vol. xxiv. p. 529.

[2] 'Boiling' and 'drying' are incorrect terms as applied to this oil: the first word implies rapid conversion of a part of the mass of a liquid into vapour, without any decomposition of that which remains behind; the second means the loss of watery moisture. Neither of these occurrences attend linseed-oil, which, being a 'fixed' oil—incapable of evaporation without decomposition—cannot be 'boiled;' and, as it contains no water, it cannot 'dry.' These terms should therefore be changed. The oil is partially decomposed during the process of ebullition, giving off certain volatile products, which escape. And the residue, when exposed to the air by being spread in thin layers on surfaces of cloth or other material, ceases to be liquid, and becomes converted into a beautiful gummy substance, or rather gum-resinous. This 'drying,' or, as it might be called, 'setting,' is understood to arise from the combination of the oxygen of the air with the oil. The oil has the property, which is not possessed by many others (fortunately, or they would not be suited for use in lamps) of undergoing a similar change without the previous heating; but the conversion does not take place so quickly, and probably results in a different substance from that yielded by the 'boiled,' or, to suggest a phrase, 'bubble-heated' oil. Though the conditions and results of this change have not been thoroughly examined, it has been shown to be dependent on the absorption of oxygen, and this view is illustrated by the remarkable fact, that if oiled silk is put away folded up before it is perfectly dry, it is apt to become very hot, and to have its texture completely destroyed. Many a new balloon has been lost in this way, being saved from being the sport of the winds abroad by becoming the sport of the still air at home. Wise states, however, that he finds oil-varnish less liable to this accident than that made with india-rubber. (See Wise, 'Syst. Aeron.' pp. 165–175).

It is really curious that the beautiful substance produced by the setting of linseed-oil is not more in use than it is for the purpose of making waterproof garments. Its freedom from oppressive odour, its transparency, lightness, elasticity, and small bulk render it an excellent material for this

posed to the air, into an elastic solid. This substance, independently of the facility of its preparation and application as a varnish, is found to answer even better than india-rubber for the purpose of making woven textures air-tight. Other materials are sometimes mixed with the oil in making the varnish, and the product is commonly diluted with oil of turpentine, for the purpose of thinning it and making it more easy to be laid on with a brush. The latter volatile oil evaporates and leaves the air-proof material on the coated surface. English varnish-makers are apt to make a mystery of their art, conceiving themselves bound to do so by the divine law of competition. Each of course has some secret, and can produce an incomparably better article than can anyone else in the world. It is probable that none of them can make a material anything like so good as a few experiments scientifically conducted would enable any careful person to prepare for himself. There can be no doubt that there is a great deal to be learned yet in the art of making air-proof varnishes; and one of the first things the 'Aeronautic Association' will have to do will be to set some good chemists to work on this matter.

Mr. Wise, an American ballooner, who has recently published an amusing account of his adventures in the air, very frankly and liberally gives us the result of his experience in the art of air-proofing gas-vessels.[1] Mr. Wise says that he prefers the linseed-oil gum to any other varnish, finding that, when carefully prepared, it requires no admixture of metallic oxides or of other substances to aid its setting or to increase its firmness. He says that

appliance. Yellow or black unsightly vestments of oiled silk are sometimes sold for gentlemen; but it is a great pity that ladies do not condescend to wear waterproof wrappers with which this really elegant material will provide them. Silks of neat patterns and sober hues, varnished with this oil-gum, form very beautiful textures, which no lady need be ashamed of. A garment made of such cloth, large enough to envelope the whole person, may be carried in a moderately-sized reticule; and, in our changeable climate, would often do good service. I believe that the elastic figures of faces and animals, which are imported from Germany, and sold in our toy shops as made of gutta-percha or india-rubber, are made chiefly of the linseed oil-gum. No doubt there is a world of uses to which it might be put.

[1] Wise, 'Syst. Aeron.,' pp. 246, 276, 307.

this substance is as hard and more permanently elastic than india-rubber; and when applied in the way which he recommends, in three or four thin coatings, it no doubt will be more gas-proof than a thicker layer of the exotic gum. Wise states that the best texture which he has met with as a vehicle for the varnish is 'Tussore silk,' a material woven in India by the natives from the cocoon of the wild silkworm. He says it is the cheapest silk sold in America, and that it is the strongest envelope material he knows. Tussore silk is a scarce article in England now; very little of it is imported; it is unknown in many of the silk-mercers' shops; a little of it is made up into light capes for gentlemen; it is neither bleached nor dyed, being of a pale drab colour. It is most remarkably strong, the fibre being much stouter than that of common silk. It is not, however, close enough in texture (at least those specimens that I have seen are not) to make a good material for gas-envelopes, it requires so much varnish to stop the pores.

There is great difference in the quality of the stuff of which balloons are made; cotton, muslin, or cambric, mixtures of silk and cotton and linen, are also used. Sometimes, however, a ballooner who takes a pride in his vessel has it woven with care of good materials. The envelope of Mr. Bell's eggoon (1850) was a most beautiful texture, so close that a microscope would scarcely enlarge the interstices of the threads into perceptible holes; this is of course essential in aerial navigation, which, not ballooning, was the aim of Mr. Bell.

M. Dupuis Delcourt launched, on May 21, 1848, in Paris a large balloon of silk prepared with gutta-percha, the only instance, he informs us, of this substance being applied in balloon-building.[1] Of other materials that have been used for the construction of gas envelopes goldbeater's-skin has long been a favourite for the small experimental balloons.[2] This substance

[1] Delcourt, 'Manuel,' p. 163.

[2] This material will no doubt ere long be entirely superseded in all its applications by some new compounds that will be obtained by organic chemistry from the domain of vegetal nature; of such gun-cotton and gutta-percha membranes give us hints. It is evident that discoveries of modern inventors and travellers are tending remarkably to substitute plant

has also been employed for making a large man-bearing balloon. M. Dupuis Delcourt made an ascent in Paris, in July 1831, with a gas globe made of 'baudruches.' Twenty thousand skins were used in making the vessel; they were placed three-thick about the lower and four-thick about the upper part of the sphere.

The same gentleman states that of late years many balloons have been made of textures treated with caoutchouc, like the Macintosh cloth. I have already alluded [1] to the recommenda-

products for animal matters in the service of human requirements. This, with the double revelation of Liebig, that farinaceous food embodies as much nutriment as can be obtained from flesh, and that flesh contains (as every one, who had thought about it, knew before), besides these nutritious matters, certain excrementitious substances, which, in killing and eating, we intercept on their road to the earth by the natural course (see a translation by Prof. Gregory of some papers by Liebig on the extracts of flesh, published in England under the cruel misnomer of 'Researches on the Chemistry of Food,' 1847), will help to a change in some of our civilised habits. These facts will hasten the day when the barbarous and disgusting practice of slaying animals for food will disappear from the earth, or be lingering perhaps only in the refinement of some such blessed people as the Kayans of Borneo. But, though there's a good time coming, we shall probably continue for some years yet to sacrifice to our tastes the moral delicacy of a few, by employing them as butchers, while they will be repaying the injury by administering to us such niceties as kreatine and inosinic acid, and other poisons subtler still, from the blood of feverous beasts—the fuel of disease. So goldbeater's-skin, the lining membrane of the intestine of the ox, will probably be used a little longer. Meantime, then, it may be worth mentioning that very beautiful small balloons are made now by a most ingenious, worthy, and therefore poor man, Mr. Weinling, of No. 3 London Street, Caledonian Road, Islington. He makes them of any shape, without visible seam, by a process of his own contrivance, of which he makes no secret. He makes, I believe, every one of those that are sold in this country by the vendors of toys and of scientific instruments. No one competes with him in *making* them, for the double reason that no one is so clever at the business as he is, and that he charges prices so absurdly low for his productions that one is ashamed to pay him, and wonders how he can make a living at all by his work. And yet in some of the toyshops you will have to pay for one of his balloons double the price which the maker would charge for it, to a person whose only labour in the transaction is that of handing the goods to you over the counter, and who will perhaps put into your hand a paper setting forth that he is the 'sole agent' for the sale of the balloons. 'Sweet Competition! Heavenly Maid!'

[1] P. 63, above.

tion, by Sir G. Cayley, of this material for the construction of envelopes. His view is that, silk being debarred by its expense from adoption for the vast gas-vessels which will have to be employed, the double cotton Macintosh-cloth would be the best material. He states that he found that such cloth, weighing about one pound per square yard, was strong enough to bear a strain of 2,500 pounds on a piece a yard in breadth.[1] He does not, however, state that he has found it gas-proof. I fear that it would be found to fail in this point after use for a time. Though very nearly air-tight when new, it is very apt to become by degrees full of minute perforations, from which, under very slight pressure, even common air will escape; and the process of patching, to stop them, is very tedious, and adds much to the weight of the material. However, no doubt the manufacture may, and would soon be, improved if a large demand for the production, for the purpose of making aerial gas-vessels, should render it worth while to expend more study upon its perfection.

M. Marey Monge, who, as I have before stated, considers that the gas-vessels must be made of some material possessing a certain degree of stiffness, strongly recommends that pasteboard should be tried in their construction.[2] He would build the envelope on a mould of papers laid upon, and pasted to, each other, and covered with a coating of marine glue. He attributes this notion to Guyton de Morveau, a physicist, who, in the early days of the balloon, paid a great deal of attention to the new art, of which he witnessed the first promise. There are, perhaps, some kinds of aerial gas-vessels which may, perhaps, be made conveniently of this material, such as those that may be required for moving large burdens at small speed, and with respect to which the saving of original expense may be more an object than the long endurance of the apparatus or the careful preservation of the gas. I believe, however, that for vessels intended for speedy locomotion this substance will not be found very suitable.

But the boldest proposal is that the gas-vessel should be made of metal. There is something fascinating to the imagina-

[1] 'Mech. Mag.', vol. xxvi. p. 419.
[2] Monge, 'Études,' pp. 24, 230, 251.

tion in the notion of heavy, rigid bodies being compelled, in spite of their weight, by means of another of their properties—their closeness of texture—to take upon them the office of purveyors of levity to our royal wants. Some such fancy as this was a very old one, as we may learn from Bishop Wilkins:—

. . . . 'If a man,' says old John of Chester,[1] 'were above the sphere of this Magnetical Virtue which proceeds from the Earth, he might there stand as firmly in the open Air as he can now upon the Ground; And not only so, but he may also move with a far greater Swiftness than any living Creatures here below; because then he is without all Gravity, not being attracted any way. . . . 'Tis a pretty notion to this purpose, mentioned by Albertus de Saxonia,[2] and out of him by Francis Mendoca,[3] that the Air is, in some part of it, Navigable. And that upon this Statick Principle, any Brass or Iron vessel (suppose a Kettle), whose substance is much heavier than that of the Water; yet, being filled with the lighter Air, it will swim upon it, and not sink. So suppose a Cup, or Wooden Vessel, upon the outer borders of this Elementary Air, the Cavity of it being filled with Fire, or rather Æthereal Air, it must necessarily upon the same ground remain swimming there, and of itself can no more fall than an empty ship can sink.'

Thus wrote Bishop Wilkins in 1638, quoting duly his elders; and if the reader, acknowledging that this Æthereal Air of which he talks is a pretty good hint of hydrogen that was to come, does not think the scheme was quite complete, he must be referred to the hack[4] quotations from one Peter Lane, commonly called Pierre François Lana, Jesuit. There he will find described

[1] Wilkins' 'Moon World,' Prop. XIV. (5th ed., 1707, pp. 122–3).

[2] 'Phys.,' l. §. Q. art. 2, 6.

[3] 'Viridar.,' l. 4 prob. xlvii. Bourgeois informs us that Father Schott—he does not say which Father or in which book—referring to Father Mendoca's scheme, remarks: 'Si une puissance plus qu'humaine parvenoit à remplir de cette matière éthérée un vaisseau construit de bois ou de lames d'airain très minces, il n'y a aucun doute qu'il y seroit soutenu sans aucun danger d'immersion ni d'autres périls, et qu'il pourroit y' être gouverné avec des voiles ou avec des rames.'—*Bourgeois*, 'Art Vol.,' p. 45.

[4] St. Fond, 'Exp.,' vol. i. p. 10; Bourgeois, 'Art. Vol.,' pp. 45, 117.

the Copper Balloons by which, in 1670, he proposed to lift men and weights into the air, and to navigate the same. His desire was to exhaust the said metal globes of air, and so render them buoyant. Now if he had been rather less practical and more theoretical, *i.e.* if he had imagined an Æthereal Air, instead of speaking of a vacuum, such as Torricelli has shown him, he would have hit off such a balloon, as has been built in modern days, to a nicety. At any rate, the two fancies put together form an excellent anticipation of nineteenth century work, a kind of prophecy at which Middle Age friars and seventeenth century Jesuits were very skilful.

There seems, indeed—and this is a curious fact—to be something about aeronautics not a little captivating to the priestly mind. For the notion of a rigid balloon did not sleep with the venerable clergymen, secular, regular, and Protestant, to whom I have above referred; it first reappears again, immediately after the early experiments with the 'taffetas gommé' and hydrogen, as coming from a Bernardine monk. Dom Gauthey [1] proposed,

[1] Nearly a century later than Lana (in 1755), and twenty-eight years before Montgolfier's experiment, Joseph Galien, a Dominican, professor of philosophy and theology in the University of Avignon, put forth a book entitled 'L'art de naviguer dans les airs, &c., &c., in which he merrily proposes to fill an enormous bag of cloth with the rarefied air of the upper atmosphere, by which it was to be buoyed up so as to float with a huge burden on the denser fluid of the lower regions. (See St. Foud, 'Exp.' vol. i. p. 13.) And Dom Gauthey was not the only priest who about the time of the balloon discovery was possessed by a desire to achieve flight and the navigation of the air. Blanchard had been pursuing his experiments in mechanical flying for some years, under the patronage of M. l'Abbé Viennay, before the new-found powers of hydrogen gave a fresh impulse to his enthusiasm (Delcourt, 'Manuel,' p. 20). On the occasion of his first balloon voyage (March 4, 1784) we find one Dom Pech, a Benedictine, seated in his car as his companion, ready no doubt to work vigorously at the wings, which at last seemed likely to be flapped with some success (St. Fond, 'Exp.,' v. ii. p. 170; 'Rev. des Mondes,' v. viii. p. 212). And soon after M. l'Abbé Miollan scandalised devout citizens in Paris by preparing to ascend in a monster fire-balloon on a Sunday, at the hour of mass; and shocked the mob so much by his machine refusing to mount at the stated hour, that they tore it to pieces (Turgan, 'Ballons,' p. 84).

By the way, it is an odd fancy this of mobs for destroying the property

in 1783, to construct a balloon of copper, and to fill it with hydrogen by means of an internal bag of flexible material, which should serve to separate the gas introduced from above from the air as it was expelled below.

But no one put the suggestion in practice, notwithstanding that M. Guyton de Morveau had recommended its trial, and that, in 1837, Sir. G. Cayley had expressed his belief that when gas-vessels come to be used as permanent vehicles they will be made of 'thin metallic sheets, kept firm by condensation with separate light bags of gas within,'[1] till in 1843 M. Marey Monge undertook to make the experiment.[2] And a magnificent experiment it was—costing its projector, single-handed, for sheer love of science, as he relates, the sum of 25,000 francs and 75 cents! In the notices which appeared in England of this machine it is spoken of as being of copper; it was, however, made of brass. The mistake arose, no doubt, from the translation of the word

of poor ballooners if they do not work well. MM. Miollan and Jaminet seem to have been the first victims. M. Deghen, who came from Vienna to exhibit his balloon and wings, was thrashed for his pains in the Champ de Mars. (Delcourt, 'Manuel,' p. 22.) The same place was the scene, a few years ago, of the discomfiture of M. de Lennox, whose 'Aigle' was there destroyed by the populace. (Turgan, 'Ballons,' p. 174.) In our own country the first attempt to amuse the people with a balloon—that of M. Moret, a Frenchman—was similarly rewarded. (Lunardi, 'First Voyage,' p. 15.) The last instance we have had of the exercise of this traditional law was, I believe, the fate, on May 24, 1838, of the huge 'Montgolfière,' which was to have started from the Surrey Gardens, by courtesy 'Zoological.'

[1] 'Mech. Mag.,' vol. xxvi. p. 420.

[2] Monge, 'Études,' pp. 25-32, 185-228. 'Ill. News.,' No. 100, March 30, 1844. There is some want of historical candour in the account of the circumstances and end of this grand but useless and ill-fated structure. It is spoken of by some who mention it as the scheme of MM. Marey Monge and Dupuis Delcourt; and it is quite evident that both of these gentlemen were interested in some way in the undertaking. But M. Monge, in the most interesting narrative of the whole process of its construction and of its ultimate failure, which he gives at length in his 'Études,' never once mentions the name of M. Delcourt. And the latter gentleman, in alluding to it ('Manuel,' p. 155), makes no allusion to the former; though he speaks feelingly of his attachment to the balloon itself, as having cost him so much labour and anxiety. (Turgan, 'Ballons,' p. 175.)

'cuivre,' which is used generically, as including both copper, 'cuivre rouge,' and brass, 'cuivre laiton.' This balloon was built of the latter material.

M. Monge states that in undertaking this experiment he wished to ascertain whether the metal, being completely inalterable by the air and impermeable by the gas, would, when sufficiently thin, answer the purpose of the envelope for an aerial gas-vessel. In considering what metal he should select he rejected zinc-plate, on account of its inferior strength and malleability; iron and tinned iron-plate, though having the advantage of strength and cheapness, are so inferior to copper in durability under atmospheric influences, that he was led to select the latter metal. And of the two varieties, as they seem to be considered in France, of this metal he was apparently led to prefer the alloy with zinc to the pure copper, by the fact that thin brass plates were to be obtained from Prussia of a larger size, and with equal thinness, of better quality and of lower price, than were then made in Paris of either 'cuivre rouge' or of 'laiton.' Accordingly, he went to work with this German brass plate, 0·0001 mètre (equal to about ·004 inch) in thickness, and weighing 0·795 kilogrammes per square mètre (equivalent to 1·465 pounds avoirdupois per square yard; built him of it a hollow sphere 10 mètres (33 feet nearly) in diameter; lined it with two thicknesses of tissue-paper, glued surface to surface, and varnished with oil, and prepared to mount heavenward.[1]

[1] But with all his care and pains his apparatus leaked; and though he laid him on material for 750 cubic metres (26,475 cubic feet) of hydrogen to fill his balloon, which required only 523 c. m. (18,465 c. f.), he could only get it three-quarters full, and stir it would not. No more money was forthcoming to supply more gas, and upwards of 90*l*. had been spent in the morning's work of making the gas already used; so the poor balloon was ultimately purchased by a brass-founder, and without any farther struggle to rise ended in the melting-pot (Turgan, 'Ballons,' p. 176).

In the attempt to fill this vessel M. Monge established the fact originally suggested by M. Guyton de Morveau, that balloons made of material which would not admit of being folded might be filled with hydrogen simply by means of a tube passing freely through the open neck and rising nearly to the crown of the sphere. Thus, as the gas entered it at once assumed its position in the upper part, displacing the heavier air, which escaped below.

M. Monge concludes, from all the results of his experiment, that metallic plate is not a fit material for the construction of gas-vessels, unless it be made of more than one thickness, so that the defects of one plate may be covered by those of another; but that the cost of making, in such case, would be too great. The price of this material, by the way, supposing it did realise the qualities expected of it, and that it were otherwise suitable to the purpose, would be in favour of its adoption, for the cost of it was 4 francs 86 cents per square mètre; [1] only half the price, says M. Delcourt, of the silk textures commonly employed for balloons.[2] I fancy, however, that these toys are not often made in England of such expensive textures as this implies.

The object sought in the use of all these different envelope-stuffs is, of course, the preventing the escape of the gas, by confining it within a vessel uniting at once the qualities of extreme lightness and impermeability. Such a material does not appear to have been yet found or, at least, to have been essayed. The reason is obvious. Tea-garden balloons being almost the only kind of gas-vessel hitherto in use, if their requisites are answered, there is but little inducement to adventurers in this line to try any improvement. Of course, all that a ballooner wants is, that his gas-bag shall retain its contents just long enough to carry him out of sight of the people he undertakes to amuse, and shall let him down safely as soon as possible; unless he may happen to have with him a basketful of amateur 'aeronauts,' who, having paid their bank-notes for a lift, are naturally inclined to get as much for their money as they can, and to make

M. Monge states that there was so little mixture of the gas with the air, that while the latter was coming out below, and the hydrogen entering above, a man could put his head into the balloon, through its neck, and keep it there a quarter of an hour, not only without any inconvenience but without even smelling the gas in the least degree. This is certainly rather surprising. It showed, however, that the process of displacement would answer in such cases, and that the internal cloth or muslin balloon of Dom Gauthey would be unnecessary ('Études,' p. 224).

[1] Monge, 'Études,' p. 30.

[2] Delcourt, 'Manuel,' p. 155.

a voyage of it. But even in this case a few hours on a summer evening is the longest time that the gas is expected to remain at work. The balloon starts overcharged with gas, rushes to the clouds, leaking, perhaps, over its whole surface, and vomiting its superfluous contents at its open neck. Gradually losing its gas and buoyancy, it soon begins to fall, unless there be a good stock of ballast in the car; if so, by throwing this overboard by degrees the machine may be kept floating some time longer.

Now, in aerial navigation nothing of this sort can be allowed. The use of the gas will not be to carry the vessel straight up to the skies, but simply to balance the burden with which it is loaded. The system must be in equilibrium, so that any force applied to it will cause it to move in the direction of its axis up, down, or in any horizontal direction. It will be necessary, too, that this state of equilibrium shall be retained as long as possible—if it were possible, from the hour the gas-vessel is filled till it is worn out. The envelope will never be emptied, except for some special occasion of repair or of inspection of the apparatus. There will not be the expense of filling for every voyage; but the endeavour will be to make the charge last for the greatest possible number of voyages. When by unavoidable leakage the equilibrium is impaired more gas will be thrown into the envelope, so as to restore the requisite floating power. Perhaps it may be impossible to make a thin material absolutely impervious to gas. The problem will be to reduce the diffusion through its texture to a minimum.

We may state, then, another of the conditions of Aerial Navigation, conducted by the aid of buoyant gas, thus:—

The envelope that confines the gas must be made of some material which is, as nearly as possible, absolutely impermeable to its contents, as well as to the air without; and which is, at the same time, as light as is consistent with being gas-proof, and which is strong enough to resist any tendency to stretch or tear it to which it may be exposed.

CHAPTER IX.

THE GAS-VESSEL—THE QUESTION OF CONTENTS.

ALL the chief requisites of the gas-vessel itself having now been considered, its contents, of course, come next under review. The gas ordinarily used in England, at present, for fitting balloons is, as everybody knows, the same coal-gas that gives us light in the streets. 'It appears,' said Cavallo in 1785,[1] 'that pit-coal is the substance which may be most advantageously used for the production of inflammable air in aerostation; and though the specific weight of this gas is greater than that of metals when extracted by means of acids, yet the cheapness of the materials makes ample amends.' However, though, as he adds, 'on the Continent various small balloons had been filled with the inflammable air of pit-coal, and had floated exceedingly well,' it does not appear that anyone ventured to use this substance as an agent of buoyancy on the large scale till Mr. C. Green filled his balloon with it, by way of celebrating the coronation of George IV. Since that time it has been commonly in use for this purpose. Occasionally, however, the luminiferous product of the gas-works is rendered somewhat lighter for the use of the ballooners by passing it through red-hot tubes. This decomposes the gas, splitting it up into other substances, the gaseous parts of which contain less carbon than the original gas, and have a lower specific gravity. The reader may be reminded that, generally, the *lighter* coal-gas is the less *light* it will give. The burner and the balloon require two opposite qualities in the gas.

Before the adoption of coal-gas by the ballooners hydrogen was almost always used as the buoyant power. Everybody

[1] Cavallo, 'Hist. Aerost.,' p. 235.

knows that hydrogen is made by treating certain metals—zinc and iron being the favourites—with water and certain acids, generally sulphuric. It is not my intention here to describe the mode in which this operation is conducted on the large scale, when hydrogen is required for balloon purposes. The process may be found described in almost every book relating to the subject, from St. Fond and Cavallo to Wise. It may be mentioned, however, that M. Marey Monge [1] suggests that where the sulphuric acid method of producing hydrogen is adopted it would be advisable to use, instead of wooden casks, a large leaden vessel for the evolution of the gas. The objection to the use of hydrogen so obtained is, and always has been, its expensiveness. Immense quantities of acid and metal are consumed, and the residual products are supposed to be of very little use. The advantage, however, which hydrogen has over all other gases in its extreme lightness is so very great, that there can be no wonder that the ballooners, so long as they were really hoping to make an art of Aerial Navigation, were slow to adopt any other in preference to it. There is one difficulty, indeed, entailed by its use, which, though it becomes a real enemy to be combated by aeronauts, is of but little importance to those who 'go up' for the public amusement. This is its ready diffusibility—the quickness with which it escapes into the air through the pores of any vessel in which it may be enclosed.

A mode of making hydrogen far cheaper than that above mentioned has long been known, and was put into practical use by the Corps of Aérostiers in the French army in 1794.[2] Guyton de Morveau proposed to the Committee of Public Safety to adopt the use of balloons for making military observations. The project was accepted, with the proviso that no sulphuric acid should be used, as all the available sulphur was required for making gunpowder. No time was lost in adapting to work on a large scale the discovery of Lavoisier, that water could be decomposed by passing its vapour over red-hot iron. Preliminary experiments were made under the direction of Coutelle at

[1] 'Rev. des Mondes,' vol. viii. p. 223; Turgan, 'Ballons,' p. 127; Delcourt, 'Manuel,' p. 86.

[2] Monge, 'Études,' p. 19.

Meudon, where an aerostatic school was established for the purpose. The best form of apparatus was determined on. The Captain of Aérostiers rushed post-haste to the army at Maubeuge, and, as soon as he had convinced General Jourdan and Duquesnoy, the Commissary of the Convention in the Army of the North, that he was not a madman or a traitor, and that it would be stupid to shoot him, furnaces and retorts were run up, and up went Coutelle, balloon, and telescope. I must ask those who take any interest in fighting matters to turn to Coutelle's account of the doings of his corps, which is printed in the works I last referred to. An account of the apparatus used is given by M. Delcourt.[1] The mode of conducting the operation will be found described by Baldwin.[2]

I am not aware whether any grave difficulties were encountered in carrying this into effect, or whether it was found to be in practice a more expensive and troublesome operation than it would seem to be in theory. Persons trying this on the small scale are apt to find their operations impeded by the increase in bulk of the metallic mass, as it becomes oxidised, and by its clogging the apparatus as it swells. This of course arises from the tubes or retorts being charged too full at the commencement, and is easily avoided. I have been informed that, some years ago, an apparatus for producing hydrogen in this manner was put up at Vauxhall Gardens, but was abandoned on account of some want of success in its application. If the experiment was tried there, numerous circumstances, other than the inability of the iron and steam to do their appointed work well and cheaply, may have led to its rejection. It is not likely that chemical or engineering science of a very high order was enlisted for the construction of the apparatus or for the conduct of the operation. The gas, too, being wanted but occasionally, the persons employed to produce it would not acquire much skill in the manufacture. And the apparatus being neglected in the intervals would be liable to get out of order. Again, coal-gas being at hand, and to be had at once by turning the taps and paying the money, would deter the consumers from taking much trouble

[1] 'Manuel,' p. 167. [2] 'Airop.,' p. 340.

to procure a somewhat lighter gas. I make these remarks, not as having any peculiar force in their application to the place of amusement just mentioned, nor thinking it the least worth while to enquire whether they apply to it at all. Very likely the experiment never was tried there; it does not matter the least. But the method must have been proposed, and perhaps essayed, somewhere, since the French aérostiers were disbanded, and most probably has been rejected or abandoned for such reasons as those which I have suggested.

I am not aware that any objections have ever been urged against the adoption of this process, which would have much weight, in any case where large supplies of hydrogen were constantly required, as, when aerial navigation comes into use, will be the case. M. Marey Morge[1] says that this operation occupied such a length of time, when tried in the early days of ballooning, that it was given up. M. Delcourt,[2] however, states that it never was used except at the balloon-school at Meudon, and in the operations of the armies of the Sambre and Meuse, and of the Rhine, and once by himself. On this latter occasion, however, the poor ballooner was cheated by the workmen employed, for they put a quantity of charcoal into the retorts with the iron, and it not only furnished him with a heavier gas than he bargained for, but nearly killed him too by suffocation. Preparations were also made by Napoleon for the employment of the aérostiers in Egypt, but the English got possession of the apparatus,[3] and so put a stop to the operations.

There is no doubt that the steam method was not adopted elsewhere, for two simple reasons; first, that no ballooners would put up a permanent apparatus when a score or two of common casks would answer all their occasional purposes; and secondly, that being necessarily migratory creatures, going gipsy-like from town to town, they could not of course make use of a set of furnaces which neither carpet-bag would hold nor diligence or carrier's cart convey. Neither are there any grounds for believing that the use of the balloon and furnaces was discontinued by the French army on account of the trouble or tediousness of

[1] 'Études,' p. 10. [2] 'Manuel,' pp. 168, 182.
[3] 'Rev. des Mondes,' vol. viii. p. 229.

the process.[1] Indeed, that the operation could have been conducted as it was, on half a hundred occasions, in Belgium and on the Rhine, amid all the makeshifts and hurry of a campaigning army, is sufficient warrant that no great difficulty could attend its use at fixed stations in a peaceful country, especially where all furnace-work is so well understood as it is with us at present, and where fuel and iron are so plentiful as in our blest soil.

If there is to be any reason for this process not being adopted, it will be that one even more economical will be introduced; of which hereafter. Where very large quantities of gas are required to be made continually—as will be the case in the air-craft posts—not only for replenishing gas vessels that require fresh gas, and for charging the new ones as they are finished, but for supplying hydrogen as fuel for numerous purposes in our factories and in our dwellings, of course the oxide of iron formed during this process, and left as the residue, will have to be reduced again to metal, again to be used as before for decomposing water.

Another gas process very similar to this last has been proposed for use,[2] but the gas yielded by it is of very uncertain quality, and, at best, contains but a small share of hydrogen. This is the method of passing steam over red-hot charcoal; by it a mixture of hydrogen, carbonic acid, carbonic oxide, and marsh gas, in proportions which vary according to the quantity and quality of the charcoal employed, is produced. I am not aware of any experiments having been made for the purpose of ascertaining what is the lightest mixture of gases that can be obtained by this process, and under what circumstances such mixture can be ensured.[3]

[1] Napoleon took a fright at balloons altogether, and would never hear them mentioned again after his coronation, because a big one, with a huge symbolic crown attached to it, sent up by Garnerin in Paris, on this occasion, went straight to Rome, and rent itself on the corner of Nero's tomb, ending its career with a ducking in Lake Bracciano ('Rev. des Mondes,' vol. viii. p. 233). This will account for Napoleon's neglecting to avail himself of the use of balloons and steam-gas in his subsequent campaigns.

[2] See remarks by Sir G. Cayley in 'Phil. Mag.' vol. l. p. 32.

[3] The specific gravity of marsh gas being 0·56; that of carbonic oxide, 0·97; of carbonic acid, 1·53; and of hydrogen, 0·069 (air being 1·00); the aim would be, of course, to produce the gases in quantity according to

I heard that in the latter part of 1853 some experiments were being tried with this water-charcoal gas at Vauxhall Gardens,

the following order: hydrogen, marsh gas, carbonic oxide, carbonic acid. If possible, the result to be all hydrogen, and at least no carbonic acid. Now the first case, in the simple process, is impossible, because for every equivalent of hydrogen set free from the water, one of oxygen is handed over to the charcoal, and goes to form carbonic oxide or carbonic acid, according to the quantity of carbon it meets with. If the latter be in great excess, there will be the greater chance of getting carbonic oxide to the exclusion of the heavier gas. Marsh gas cannot be reckoned on; it appears to arise at least from impurities in the charcoal, and will not be present in any considerable quantity; and if it be not due to this cause, it must be a direct subtraction from the available levity of the hydrogen, being formed by the condensation of this gas into union with some of the carbon—if this is possible. The most favourable case, therefore, is that in which nothing but hydrogen and carbonic oxide are obtained. And from the manner of their origin, the only proportion in which they can be formed under these circumstances is that of one equivalent of each. Now every nine pounds of steam consist of one pound of hydrogen and eight of oxygen; and when the steam splits up in the retort, these eight pounds of oxygen take to themselves straightway six pounds of carbon to form carbonic oxide. Therefore every pound of hydrogen will be accompanied by fourteen pounds of carbonic oxide. Again (at a standard temperature and pressure), 100 cubic inches of hydrogen weigh 2·137 grains, and 100 cubic inches of carbonic oxide weigh 30·207 grains. So that 1 lb. or 7,000 grains, of the former gas (H) occupy $\frac{7000 \times 100}{2\cdot137} =$ 327562 cubic inches: and 14 lbs. of the latter (C. O.) occupy $\frac{14 \times 7{,}000 \times 100}{30\cdot207}$ $= 324428$, cubic inches. And the whole bulk of the 15 lbs. (or 105000 grains) of gas will be 651990 cubic inches. 100 cubic inches of the mixture will weigh $\frac{105000 \times 100}{651990} = 16\cdot1045$ grains. But 100 cubic inches of air weigh 30·822 gr. (Regnault). The specific gravity, therefore, of the mixture will be $\frac{16\cdot1045}{30\cdot829} = 0\cdot522$. It appears, then, that the result of this process would consist of nearly equal *bulks* of hydrogen and of carbonic oxide (about 320,000 cub. in. of each in the 14 lbs. of gas). And the gas thus obtained would be rather more than half as heavy as common air, being of about the same specific gravity as coal gas of good illuminating quality. Indeed, on referring to the first text book at hand (Knapp's 'Chemical Technology,' Engl. trans. by Ronalds, vol. i. p. 215), I find in a table quoted from Christison and Turner, the number 0·529 given as a mean specific gravity of coal gas, taken from six different specimens, almost the very same

for the purpose of applying an invention of a French gentleman for obtaining artificial light by platinum heated to whiteness in a jet of this hydrogen or of carbonic oxide, or of a mixture of them. I was informed that it was intended to use the gas for the purpose of inflating balloons. I am not aware what result, as to lightness, was obtained. The process is not, however, likely to be productive at a cheap rate of gas of a desirable degree of lightness. I have thrown the grounds for this opinion into a footnote (p. 114), to avoid loading the text with dry chemical details. It would appear, that without complicating the process to an extent that would probably make it as expensive as coal gas, we should not obtain a more buoyant product than can now

as that deduced above for the hydrogen and carbonic oxide mixture. However, coal gas is not generally so good (for *light*) as this would imply; 0·476 being stated by Hedley (as cited by Knapp, vol. i. p. 217) as the average specific gravity of the produce of the English gas-works; and, in fact, gas below the average of specific gravity (about ·41) may always be obtained from the factories. It would appear, then, that the best gas that can be obtained by this method is less buoyant than common coal gas. If any substance were known which, by a simple practical process, would absorb and fix carbonic oxide at a cheap rate, so as to separate it from hydrogen, we might avail ourselves of it to obtain pure hydrogen, by subjecting the result of the steam-coke operation to such treatment. Unfortunately, however, this property is not known to belong to any substance at all applicable to our purpose, so we could not improve our product so obtained.

There is, however, another form in which the experiment may be tried. Gmelin states that if steam be passed in excess over a small quantity of charcoal, carbonic acid is produced as the chief accompaniment of the hydrogen, with but a small quantity of carbonic oxide (Gmelin's 'Handbook of Chemistry,' Engl. transl. by Watt, vol. ii. p. 88). If, then, we can get all the oxygen of the water to form carbonic acid instead of carbonic oxide, we may improve our result; for though carbonic acid is grievously heavy (being of sp gr. 1·529), we shall not only have a smaller bulk of it mixed with our hydrogen, but we may remove it more or less completely from the mixture. Carbonic acid being readily absorbed by a variety of matters—caustic lime, for instance—the hydrogen might be freed from its parasite by passing it over lime. In this case, however, the expense of burning the lime to drive off the carbonic acid, and prepare it for another treatment, or of purchasing fresh lime for each operation, would have to be taken into account. I fear this plan would be fully as expensive, and more troublesome, than the steam-iron process.

be obtained at a cheap rate at the gas-factories. The expense of the simple process cannot very well be estimated, as it will depend partly upon the amount of fuel necessary to be burned in the furnaces outside the retorts for the purpose of keeping them up to the temperature requisite for decomposing the water.

The inflation of gas-vessels with heated air, according to the method of Montgolfier, has been so very little practised of late years, and there are so few detailed accounts of the experiments which were made with fire-balloons in the early days of the invention, that it is scarcely possible to form a judgment as to the extent to which this method may be applicable in aerial navigation. It would appear, from the account of Montgolfier's first public experiment,[1] that the lifting power of the balloon indicated that the average specific gravity of its contents was about ·5. This, however, probably gives too high a value to the buoyancy of the rarefied air (see note, p. 120). But the rough method of generating the heat which was adopted in this, and with very little real improvement, in the other experiments of this kind which are recorded, renders it quite superfluous to enquire what results were obtained as respects the lightness of the contents of the envelope. If hot air were resorted to in aerial navigation as a means of floatage, the heat would be obtained by some more organic method than that adopted by the first ballooners, and would be economised by appliances for retaining and regulating it which have never been tried. The greater lightness, and, apparently, greater safety of hydrogen, caused it so soon to supplant the hot-air plan in the favour of the public, that the latter has never had a chance of being developed. If we were not blest with the possession of hydrogen, there is no doubt that aerial navigation might be accomplished by the aid of heat alone. Indeed, the advantages which the method of the Montgolfiers presents, in the rapidity with which the gas-vessel may be charged, and the cheapness of the process, render it very likely that there may be some branches of aeronautic practice in which expanded air will be preferred to the permanently light gas.

[1] St. Fond. 'Exp.' vol. i. p. 4.

These advantages which belong to the hot-air vessel are so great for the hour's amusement of the ballooner, that it is quite wonderful that they have not led to the general use of the fire-balloon for these shows. A very small amount of ingenuity would extinguish every spark of danger in their use. It must be remembered, however, that rapidity of filling and cheapness of production will be by no means so important an object in the aeronaunomy of the future. First, because hydrogen will be almost as cheap as coke, equivalent for equivalent, or of price not more than double that of the solid fuel—as I shall hope to show hereafter; secondly, because this gas, being in the future days kept in store, and not always made just as required for use, will be able to be thrown into the aerial vessels as fast as it can flow through pipes, which it can do faster than any substance in the world; thirdly, because when the gas-vessel is once filled, it will be filled for a permanency—like a pillow stuffed—the contents not be moved or changed except on occasional necessity. To this must be added the consideration—very important for the rapidity of motion that will be required in most cases for the transit of the air—that the vastly inferior lightness of the hottest air that we are likely to be able to keep in a large gas-vessel, as compared with that of hydrogen, will render necessary a much greater bulk of the gas-vessel for the rarefied air than is required of hydrogen to obtain equal lifting power. This latter drawback is, to the *ballooner*, only a question of expense in the original construction of his apparatus; which would be more than requited by saving due to the cheapness and speed of filling on each occasion of use. But with the air-sailor it becomes a matter of increased resistance offered to his craft by the air—which for him is the most serious of disadvantages.

Count Zambeccari [1] seems to have made some endeavour to improve the appliances of the hot-air balloons, but he has not left any hints, so far as I can learn, likely to be useful to our art. The late Col. Maceroni advocated the use of fire-balloons,[2] not for the purposes of aerial navigation, which he considered impossible, but as a means of rising into different currents which

[1] See p. 68 above.

[2] 'Mech. Mag.' vol. xxv. p. 408.

might transport the craft. He rightly considered the danger of the practice to be nothing, but committed the error of supposing that no kind of gas-vessel would be at all manageable in the air so as to be moved by force exerted within it.

No attempts, however, as I have said, have been made to ascertain what are the lifting powers of hot air, or rather, to what temperature air confined in a large vessel can be heated; for if the temperature is given, its buoyancy is known. Nor do we often hear of any use being made of it at the tea- or beer-gardens.[1] So we have no facts, accurate or rough, on which a judgment can be formed as to the amount of assistance which hot air, as a means of sustaining weight, may render to aerial navigation. We only know that there is a practical limit beyond which it cannot serve, and which is determined by the density of the air at different temperatures,[2] and by our certainty that we cannot

[1] It may be worth mentioning that, although Montgolfières have been so little used in this country, the first balloon ascent made in this island, namely by Mr. Tytler, at Edinburgh, on August 27, 1784, was made in a fire-balloon.* The *first* experiments with balloons, that were made before it was generally known that they were not navigable, are truly attempts at the aeronautic art, and as such may be noticed here.

Mr. Hampton's proposal in 1850—and more than proposal, too, for he actually built the balloon, though it was not finished till too late for the ship that was to have taken it—to assist the search for the missing Arctic voyagers by means of a captive fire-balloon, so admirably suited to the purpose, being an effort in the cause of humanity, is worthy of record. Mr. Hampton had already given proof of his courage by two parachute descents which he had made—being, I believe, the only person now living who has tried this experiment. Parachutes will some day be something more than baits for the lovers of catastrophe—they will have to be navigated.

By the way (a note is a bit of moor-land in a park, kept to ramble in) here is a remark of M. Dupuis Delcourt well worth thinking upon:—'A-t-on fait pour ces essais [aéronautiques] des dépenses qui soient comparables à celles que coûtent tant de vaines tentatives pour vaincre les obstacles que présentent, et présenteront probablement toujours, les mers Polaires?—obstacles que tant d'expéditions inutiles doivent faire croire invincibles, et que la navigation aérienne anéantirait pour toujours.' ('Manuel,' p. 151.)

[2] Let us assume the temperature of the outer air to be 15° Centigrade

* Mason's 'Aeron.' p. 270; 'Literary World' No. lxx. July 25, 1840.

keep at a very high temperature large masses of air enclosed in a thin shell, which must be constantly losing heat by radiation, and robbed of it by the contact of the outer atmosphere.

Hydrogen then, it seems, is preferable to every other agent of buoyancy that can be used for ordinary purposes of aerial navigation. How, then, is the hydrogen to be obtained cheaply? The reader who is not versed in chemistry may be informed that all the methods of procuring hydrogen which have been tried or proposed, depend upon the decomposition of water. There is probably no other substance in nature from which it can be obtained at all on the large scale in any degree of purity; certainly none which will yield it so readily and in such quantities.[1] In both of the operations which have been applied to filling

(50° Fahrenheit), that of a moderately warm day, and that we can keep the contents of the gas-vessel heated so highly as to be equivalent to maintaining the whole atmosphere within the envelope at 100°. Now we may compare the density of the rarefied air within to that of the air without, just as if they were two dissimilar gases; and, taking the outer air as the standard, we may then conveniently speak of the specific gravity of the contents of the envelope with respect to common air.

The experiments of Magnus and of Regnault have informed us that the expansion of the air between the limits of the freezing and the boiling point of water, i.e. from 0° to 100° of the Centigrade scale, amount to ·003665 of its bulk for every degree of that scale. Again, the densities of gases are inversely proportional to the volumes occupied by a given weight of them. Taking, then, the density of a volume of air at 15° as the unit for comparison, and calling this volume v, we shall have the volume of the same quantity of air at $100 = v = v\,(1 + (100-15) \times \cdot003665)$. If then d represents the density of the air at 100, as compared with its density at 15°, we have $d = \frac{v}{v'} = \frac{1}{1 + 85 \times \cdot003665} = \frac{1}{1\cdot311525} = \cdot7625$. In the case supposed, then, this specific gravity will be about ·76.

This is not a very promising degree of levity; and we can scarcely assert whether or not a much higher temperature can be given to the enclosed air. It is likely that the early experimenters estimated too highly the weight carried up by their heated air, and consequently that the degree of rarefaction was not so great as they inferred; for their heating apparatus was of the rudest description that could be contrived. Experiment only can determine to what extent our present improved means of applying heat would enable us to make use of this principle in aerial navigation.

[1] See p. 33.

balloons the water is decomposed by a metal—iron in one case, with the aid of heat; iron or zinc in the other, with the aid of an acid; the heat and the acid, each in their own way, promotes the oxidation of the metal at the expense of the water, and so sets free the hydrogen. The advocates of aerial navigation [1] generally hope to cheapen this latter process by finding some use in the arts for the sulphate of zinc or of iron, so that by the sale of these secondary products the cost of the gas might be lessened. It is very odd that it never occurred to them that these same sulphates would be more useful to the hydrogen-makers themselves than to any other people. But of this I shall have to speak hereafter in treating of the means whereby I would propose to procure the supplies of gas. Another of our conditions may be stated thus, combining, under one head, the general with the special requisite as respects the agent of buoyancy.

The envelope must be charged with the lightest possible gas, and for this purpose means must be found of producing hydrogen abundantly at a cheap rate.

[1] Monge, 'Études,' p. 17.

CHAPTER X.

THE AIR-CRAFT—THE QUESTION OF FLOATAGE.

Having now determined that we must charge our vessel with the most buoyant gas we can get, we must consider what it is that this agent is to do for us. Its potency will, of course, depend upon its quantity, so that in assigning its function we shall find the ground for determining what, in any case, is the amount of it that we require. We have already settled very decidedly what duty it is not to be expected to perform,[1] viz. that of altering the height at which the craft shall float in the air, in the way of enabling it to fall by waste of its own powers. That neither is it to be required to do the work of lifting the air-craft skywards is but a corollary of the proposition which is implied at the outset of our inquiry, though we have not yet formally considered it; namely, that we must have power to propel us. If we must have an agent of horizontal progression, we shall of course be provided thereby with the means of motion in any other direction.[2] No one, indeed, can see a balloon bolting from the earth and hurrying with its occupants to the clouds, without being assured that since that road leads to no place on earth, and since the first object of aerial navigation must be travelling from point to point of our planet, no such mounting force is requisite, or even useful.

We had, indeed, defined the services of our buoyant gas at the very entrance of our subject, by the statement that of the two modes of neutralizing the weight of the body to be lifted into the air, we should accept that afforded by the use of a buoyant counterpoise. The function, then, of the contents of the

[1] See p. 69. [2] See p. 74.

envelope in aerial navigation, is not to lift the craft from the ground, but simply to neutralize the downward pressure of its weight, and to set the system free to move in obedience to any force, other than that of gravity, that may act upon it.

This, however, is no new discovery of mine; it must be a condition that would present itself to the mind of almost every speculator in the art. For the sake of illustration I will quote a few passages in point. Mr. Walker, a schemer in flight, who was busy at the beginning of this century, writes thus:—'But for this kind of navigation the balloon must be much smaller than usual, and perfectly spherical, and the gas should be kept in such a degree as not to have too great a tendency to ascend—it should be so regulated as to float in equilibrium with the atmosphere; the aeronauts could then keep the machine at a moderate height—from fifty to a hundred feet would be high enough for ordinary sailing.'[1] A later enthusiast, Mr. Hamilton, remarks:—'The man flying with wings can be provided with the accompaniment of a small balloon, of that exact degree of power of ascension that shall equal his own personal weight when equipped for flight; that is to say, be an exact counterbalance to the gravitation to which all matter is subjected in proportions known to science.' The notion is excellent, notwithstanding the oddness of the language.

M. Sanson puts it quite as quaintly:—'Le navire aérien, quelque léger qu'il soit, doit toujours excéder en pesanteur l'énergie du gas qui tend à déplacer l'air, afin d'éviter l'entraînement vertical et irrésistible dans l'espace par lequel il est dominé, ce que nous appelons ascension, et qui est aussi une sorte de submersion complète dans l'air.'[2] This gentleman has a wholesome terror of being precipitated into space by what he calls the 'attraction céleste,' so he determines to be on the safe side by having a little excess of weight. And perhaps the precaution may have its uses.

It is probable that this principle has never been deliberately tested by any experimenter with balloons even in the early days

[1] Walker, 'Treat. Flying,' 1810. Abridged in 'Mech. Mag.' 1827, vol. vii. p. 207. Hamilton, 'Ess. Flying' (1841), p. 10.

[2] Sanson, 'Navig. Atmosph.' p. 11–12 (1845).

of the endeavour to harness the new power to the uses of man. Firstly, because trials of this sort being very expensive, the individuals who have undertaken them have generally made their endeavours in public, for the sake of getting the expenses paid; and, in such case, it is quite necessary to be sure of having plenty of rising force at command, to get away from the mob; because if the apparatus did not work well it would be certain to be torn to pieces.[1] Secondly, if, by co-operation, the experiment had ever been fairly prepared for trial by the first ballooners, it is most likely that they would have been discouraged from proceeding, and would have considered that it failed because they would have found that, however nicely counterpoised the burden of their boat might be, it still required great force to set it in motion quickly. Though the weight of the apparatus might be quite neutralised, the first flaps of a small wing would scarcely move it at all. An oversight very easy to make would lead those who might witness such a result to conclude that wings were powerless. I think it very possible that this may have happened more than once, and perhaps may have resulted in the destruction or abandonment of the experimental machine.

The inertia of a large mass of matter is of course a very serious impediment to sudden motion. There is, perhaps, no case in nature in which we can witness the effect of pure inertia in such perfection as in that of a heavy body just buoyed up in the air to equilibrium by a light gas. In all other cases the resistance of the inertia is complicated with the effect of liquid pressure or of friction. The nearest approach to it is the condition of a large body floating in water, but here the resistance of the water to its motion is considerable, even on its commencing to stir. In the air, however, the resistance to the first slow movement is so slight that it may pass as nothing. In other instances, such as that of a heavy door well hung, of a large fly-wheel, or of a carriage on a railway, the friction of the solid supports adds of course very greatly to the reluctance of the body to move. A large and heavy balance-beam poised on a knife edge passing through its centre of gravity, would, so far

[1] See p. 105 note.

as motion about its axis is concerned, be in the same condition as a big air-craft counterpoised. But the case is so far different that the heaviest part of such a body being necessarily, for strength's sake, placed about the fulcrum, where the actual displacement is very small, the amount of motion produced by any disturbing force is in reality very slight.

An air-craft, then, with its weight exactly neutralised by the gas within its float-vessel, though it is virtually lighter than any feather, and will require no more force to lift it a hundred feet than it would to push it horizontally to a similar distance, requires a considerable force to move it at all. Its behaviour is totally different from that of a floating feather. Any force, it is true, however slight, will move it, but the quantity of motion produced will be proportioned to the amount of the force exerted and to the time that its action continues conjointly. A breath, if continued long enough, will drive it forwards. If an enormous power should suddenly pluck at it, it might rip the part seized away from its bearings without stirring the vessel; as a tallow candle shot from a gun plunges through a thick door, free on its hinges, without moving it; or as a runaway horse dashes through a turnpike gate without injuring his limbs or its fastenings. Time is required to set it in motion, and when once moving time and force are equally necessary to arrest its progress. This latter point will be of the highest importance to be remembered in aeronautics.

However, the behaviour of air-craft with central buoyancy has been illustrated intentionally on a small scale, and incidentally on a practical scale. In 1840 Mr. Green exhibited at the Polytechnic Institution in London a miniature balloon armed with screw-propellers driven by a spring, for the purpose of showing that it was possible to move such a body at a certain slow rate horizontally or up and down, for the purpose of seeking appropriate currents.[1] 'The balloon being filled with coal-gas, was then balanced; that is, a sufficient weight was placed in the car

[1] He was at that time contemplating a balloon voyage across the Atlantic. Mr. Wise, the American ballooner, has several times endeavoured to get the means of making this trip, and has been recently stated to be about preparing for it.

to keep it suspended in the air, without the capacity to rise, or inclination to sink. Mr. Green then touched a stop in the spring mechanism, which immediately communicated a rapid rotatory motion to the fans, whereupon the machine rose steadily to the ceiling, from which it continued to rebound until the clock-work had run out. Deprived of this assistance it immediately fell.'[1]

Now there are three possible cases as respects the buoyancy of the air-craft. Either it may be in excess, the gas system

[1] 'Mech. Mag.' vol. xxxii. p. 480.

I quote the following very suggestive paragraph from the interesting book of Mr. Wise, the American ballooner, on the practice of his craft. 'If we take a balloon of limited size, about 18 feet in diameter each way, it will, when inflated with hydrogen gas, be capable of raising 160 lbs., independent of its own weight. Now if this be so fastened to a man's body as not to interfere with the free use of his arms and legs, he may then ballast himself so as to be a trifle heavier than the upward tendency of the balloon, which will be nearly in equilibrio. If, then, he provides himself with a pair of wings, made on the bird principle, with socket joints to slip over his arms at the shoulders, and a grasping handle internally of each one, at the same [?] distance from the shoulder-joint of the wing as the distance is from his shoulder to his hand, he may beat against the air with his wings, and bound against the earth with his feet, so as to make at least a hundred yards at each bound. This the writer has often done, in the direction of a gentle wind, with the aid of his feet alone, after his balloon had descended to the earth; and on one occasion traversed a pine forest of several miles in extent, by bounding against the tops of the trees.'—Wise, *Syst. Aeron.* p. 22.

That great leaps may be taken in this way there can be no doubt, but that they can be taken with any considerable speed in a horizontal direction against the atmospheric resistance to a sphere of 18 feet in diameter is certainly impossible. Such wings, too, as this author suggests, would be of very little power (see p. 23, above). A person thus balanced by a balloon might jump to a very great height vertically, because as soon as he relieved the gas of the burden of his body by springing, it would begin to mount with an accelerating force equal to his weight, till the momentum of his body was destroyed by gravity, and then the momentum of the balloon would continue the ascent till the resistance of the air arrested it. In a horizontal direction his propelling force will be the least possible; firstly, because his weight being taken off the soles of his feet, they will have no hold, by friction, on the ground; and secondly, because most of the force he might put forth in the forward direction would be wasted in tending to swing him round the balloon (see p. 24, above). I shall have to return hereafter to this mode of locomotion.

having, like the balloons, a certain rising power; or the weight of the load may surpass the levity of the floatage; or the two may be in exact balance. Before finally fixing our choice upon the latter condition, it may be as well to show the reasons of our preference. If our vessel has a tendency to mount while we wish to move horizontally, its upward efforts must be counteracted by force exerted from within the air-craft—by levying, in fact, a constant tax to this extent upon the power available for propulsion. This state of things involves, therefore, an unmitigated waste of power, a double waste both of lifting gas and of working mechanism. If, on the other hand, we leave a part of our burden to be lifted by mechanical force, we are not making the best bargain for ourselves with gravity. Either we must make a sacrifice of attainable speed, or we must carry more power to combat gravity; in the latter case, of course, more gas must be taken in to lift the extra machinery, which gas might just as well be used at once to buoy up the burden. So there is a waste of power in this case too. There may be an advantage to be gained in certain cases by the adoption of either of these conditions, but the reason stated is sufficient to exclude them both as rules for general practice. It must be remembered, too, that a mechanical force acting on the air, and sufficient to buoy up a certain burden at the surface of the earth, will not be adequate to neutralise the same weight at a greater height in the atmosphere; because the wafting surfaces remaining the same, the amount of resistance offered to them by the rarefied air will be diminished, so that to obtain the required resistance they will have to be moved with a greater velocity.

If the weight of the craft is exactly counterpoised by the floatage, the work cut out for the propelling force is reduced to the simplest possible condition. The whole effort is to be made precisely in the direct line of progress. The immense advantage that a perfectly-balanced air-craft possesses over birds is obvious. The whole of its power will be available for producing speed. In all flying animals it is probable that by far the greatest portion of the force of the wings is expended in supporting their weight.[1]

[1] Perfect flight is probably one of the most complicated actions in nature. The analysis of the phenomenon is extremely difficult, both as to the mode

If the whole force put forth by a swift was employed in propelling him, his velocity would probably be quite awful. His

in which the compound force is transmitted from the air through the wing to the body, and as to the functions of the different parts of the outer mechanism in taking hold of the air. In the first place neither are the wing-arms levers, for there is no fixed fulcrum, nor do the forces acting on them form a 'couple,' for the body does not twist round any axis whatever. If one wing alone acts, a true couple is established, and the whole system will turn round an imaginary axis; but when both are working equally, the movement is in the direct line of the resultant of the two forces, each of which is the resultant of others—of how many need not now be determined.

Again, as to the mode of action of the wing upon the air. There are three ends to be effected. Firstly, the weight of the animal is to be lifted; secondly, the body is to be propelled; thirdly, since the action of the first force is alternate, the system must be prevented from falling during the interval of the up stroke. Here it must be noted that there are two distinct kinds of wings in nature—the jointless vanes of insects and the flexible wafts of pterodactyles of bats and of birds. And among insects there are two arrangements: that of the single pair, and of two pairs of flying-limbs. Where there is but one unbending wing on each side, as among the true 'flies,' we may be pretty certain that the wing executes a different function at different parts of its stroke. In insects with two pairs of wings, one pair probably does the moving work, while the other provides the sustaining agency. This latter function is, no doubt, executed by the stiff wing-shield of beetles, whose hinder wing, not so metamorphosed, takes the active duty. With butterflies—and more especially with sphinx moths and dragon-flies, which are the true aerial types of their circle—the fore-wing must be the propeller and lifter, while the hind-wing is the parachute.

With bats and birds, however, the case is different. In each of these we have a single wing on each side, with two chief joints, in the true or engineer sense, as hinges, dividing the limb into three joints, in the false or butcher sense, as links:—the arm, the wrist, the finger. Now I think it most likely that each of these three links, and the part of the web of which they form the frame, execute specially a peculiar share of the three-fold function, not exclusively, but chiefly.

One point is quite obvious to the most careless observer of the organic mysteries—that the wings of the fastest fliers are much longer, but not broader, than those of the slow-moving creatures of the same size. This is as remarkable in, for example, the swifts and the humming-birds, as it is in the great insect air-craft just now instanced. It is quite clear that it is the length of the primary quill feathers that promotes the speed of these birds. The mode is obvious—the longer the radius the longer the arc of motion; the greater, therefore, the space traversed by the end of the wing in equal times, and the greater the resistance and purchase on the air.

wings would be simple vanes moving directly fore and aft. Just such, of course, is the case with the balanced air-craft; the move-

It is equally certain, for the converse reason, that the tertiary feathers, which are attached to the shoulder-link, close to the body, and which move through the arcs of but small circles, and therefore through very small spaces, cannot contribute much to the active work. But they are always broadly and fully developed, and must serve some important use. Their function must, therefore, be that of sustaining the body during the up-stroke of the wing. This, of course, will be effected by the raising of the fore-edge of the wing, and the lowering of the feather ends behind, so as to form an inclined plane sloping backwards, on each side of the body—a kite, in fact, on which the body is enabled to rest by virtue of its onward impetus. Most birds in making the return stroke fold their finger-ends, or primary feathers, backwards, so as to add their surface to the extent of the parachute-kite, while they remove the resistance to the up movement, at the long outward arc. It was this part of the wing function that Mr. Hudson proposed to imitate in his much-talked-of flying project, which the newspapers were paid to extol so magnificently a few years ago. (See 'Mech. Mag.' Nos. 1,025, 26, 27, 28, 31, 33, also an Essay by Mr. Monk Mason in the 'Civil Engineer and Architect's Journal' for May, June, and July, 1843, and 'Athenæum,' No. 806.) The notion was very ingenious, but the author of it could not make the long primaries and the muscles to work them, and he omitted to provide means of effectually keeping the system in its horizontal level.

The remaining function I should suppose to be executed mainly by the third part of the wing, by the wrist-link and secondary quills, whose distance from the body and extent of surface will enable them, during the downward stroke, to obtain from the air a great part of the resistance required for the counteraction of gravity. They again will, of course, help the tertiaries, in the kite action, during the interval of recovery; and will be assisted in turn by the primaries in doing their lifting work.

I beg to refer the reader for an excellent outline of the general structure of the various kinds of bird-wings to one of Mr. Swainson's charming volumes in the Cabinet Cyclopædia—'The Natural History of Birds,' vol. i. p. 79. However, neither he nor any author with whom I have met, gives a satisfactory analysis of their functions. In Appendix A will be found a list of books and papers relating to flight.

As ornithology is but a branch of the science of aerial navigation, I must make a remark respecting the classification of birds which I have long hoped some one else better qualified to do so would propound. Most scientific men are apt to think that all attempts to represent nature in numerical harmonies are visionary fancies, beneath the dignity of science. Now I think humility, not exalted dignity, is that which knowledge teaches most

ment and construction of the propelling agents will be reduced to the simplest possible conditions. But of this hereafter.

impressively, and I cannot look at any branch or twig of nature without believing that an orderly arrangement pervades the whole; and number is the very key to all order, without which it may be beautiful, but must be imperfectly intelligible, like music to a person who has been taught in early youth to believe it only an accomplishment which it may or may not pay for him to learn. Fortunately, however, a few philosophers, such as Pythagoras of Crotona, and Macleay, author of the 'Horæ Entomologicæ,' have not thought considerations of number beneath their notice, and I shall take leave to follow them.

Most of the attempts to arrange nature in harmonious groups have failed, for two reasons. Firstly, by reason of the endeavour to crush into a line that which can only be properly represented by a surface. The ordinary classifications are linear, of one dimension, on the chain principle. The arrangements which, like that of Swainson, occupy a flat network approximate to a correct representation of nature. The other error has been that of adopting a wrong key number; some idol of the cave which, shutting out from view the large expanse of nature, has guided observers by hints taken from too narrow a field. I took occasion to observe in a former page that man's life was ruled by the number three. (See p. 20 note.) Now the old doctrine of macrocosm and microcosm is good: man is the compendium of the world. That the number three is the frame in which the physical world is set geometrically, the only three possible dimensions of matter—length, breadth, thickness—assert. That chemically it bounds its existence, the three states of substance—solid, liquid, fluid—affirm. That organically it rules the earth, the three provinces of nature—mineral, animal, vegetal—are evidences. I shall trace the law no farther, leaving it to more cunning hands, or to future hours; but I must maintain that a ternary harmony runs through all nature—an infinite order of correspondences. The only place in which I have seen this pointed out is in a good periodical now defunct, ('Politics for the People,' J. W. Parker, 1848, p. 189), by a contributor who, perhaps, is deceased too. But as Mr. Willowwren stops just short of my point, I shall not be plagiarising if I follow up the idea.

It was of the classification of the natural navigators of the air, that I was about speaking. Birds are of course a class of the vertebrated animals; but here they are one of three, the 'hairy, scaly, and feathery;' of which the first and second correspond to the mammals and to the fishes and reptiles respectively, and which dwell chiefly about the land, the waters, and the air—solid, liquid, fluid. One of the organic laws seems to be, that, of each triad, one branch is more divergent and variable than the others. The scaly is the expanding member of the vertebrate order. Now the error which seems to me to have been made in arranging birds has arisen from

It should be remarked in this place, that though the bulk of the buoyant gas is increased as it rises in the atmosphere, its lifting power remains unchanged. For the air outside the gas-vessel expands in an exactly equal ratio; so that, though the specific gravity of the gas with respect to the standard air is vastly lessened, its specific gravity with respect to the air which it displaces is exactly the same as it was before the expansion took place.

However, changes of temperature will affect the lifting power of the gas considerably. To what extent this variation will occur it is impossible to predict, because it is impossible to know what will be the relations of the temperature with the gas-vessel to that of the air without. All gases expand or contract, as is well

a neglect of this law, and from a too ready adherence to traditional notions. Mr. Swainson required scarcely any twisting of the ordinary classifications to adjust the chief groups to his quinary system. It had seemed natural before to divide the birds into the five classes of preyers, perchers, scrapers, waders, and swimmers, so the usual views fitted well to the new device. But that this is not the true interpretation of nature will, I have no doubt, be allowed at once by many, when it is suggested that there are really no grounds whatever for separating as an order the 'raptorial' birds, usually so distinguished, from the other land birds. There are rapacious birds quite as emphatically prey-catchers among the swimming birds as any of the falcons. Neither is it easy to draw any distinguishing line between the waders and the poultry-birds or scrapers. There are no differences in their feet so marked as those between the hinder limbs of many birds grouped together as perchers; for instance, the swifts and the woodpeckers. If, however, we refer the feathered class to a fundamental triad for comparison—for instance, to the solid, liquid, fluid—they distribute themselves at once into a trinity of groups. The land-birds, the water-birds, the air-birds, the last being the typical order: the walkers, the swimmers, the flyers. The first order includes the poultry-birds and the waders, by which they pass to the true water-birds; and the air group includes the perchers and all the 'raptores,' which are clearly only the preying family among the flyers. It is indeed most curious that the falcons and their immediate relatives have been so set apart for honours as an order by themselves. I presume the mistake is but symptomatic of an ancient respect for predatory idleness and pride of family—a superstition of which the mind of the peoples is rapidly becoming disabused. These notions must for the present be sufficient as hints that a reconsideration of the ground on which birds and some other animal-classes are established is desirable.

known, ·003665 of their bulk for every degree (Centigrade) of increased or diminished temperature;[1] the gas within the gas-vessel and the air without will therefore be liable to considerable variations of their density, but to what extent they will each be affected cannot be anticipated; and the differences between the affections of the two fluids will vary according to the material and construction of the gas-vessel.

These general considerations, however, are worth mentioning. The upper regions of the air are very much colder than the lower, the cold gradually increasing with the height. The heat of the sun passes through the air without warming it. The air derives its warmth only from the surface earth, as the earth is heated by the sun. As the air at the surface of the earth is warmed, it is expanded, and rises till the whole heat it contained is converted into expansive force, and it becomes cold as well as rarefied. Any part of the air, as it is heated or cooled, being free to move, immediately obeys any impulse to rise or fall which it may receive from changes of temperature, and in doing so mixes itself in all directions with other air, and so neutralises all slight variations, no portion of it ever being able to accumulate warmth.

On the other hand, the gas within the gas-vessel, if it is not poured into the envelope hot from the generating apparatus when it is received, is at least charged with the temperature of the bodies on the surface of the earth at the spot. This temperature in the day time, when the earth is warm, must always be greater than that of the air lying upon it, because as fast as the air is at all warmed at the surface, it must rise to allow colder air to take its place. The gas confined within the envelope being unable to rise freely and mix with the outer air, must retain the advantage in temperature which it has over surrounding bodies, until it loses it by radiation from, and by contact of the colder air with, the outer surface of the gas-vessel. The gas within the envelope is, unlike the outer air, liable to gather heat from the sun, not as being able to receive heat directly from his beams, but because the solid shell of the gas-vessel, being heated by them, imparts its warmth to the gas in contact with it within, as well as to the air without: the latter rises, and, escaping, is replaced by colder air from above; the former, being pent up, can only effect such

[1] See p. 120.

circulation within its own limited mass, which therefore must increase in temperature. The reverse will take place during cold nights, radiation from the walls of the gas-vessel will carry off warmth from the fluids in contact with it on both sides. The air without being cooled will fall, and will be replaced by warmer air from below, while the gas within being debarred from this general interchange will be subject to the full effect of the change of temperature. The general result is that the contents of the gas-vessel will be liable to variations of temperature, which will cause its buoyant power to vary, but to what extent it is impossible to state. Means, however, must be taken to rectify and compensate these changes.

Temperature, however, is not the condition whose alterations will affect the floating equilibrium of the air-craft most powerfully. The condensation of atmospheric moisture on its surface will probably be the cause of the most serious irregularities in this respect. It is needless to repeat here observations that have been made already on this matter. The leakage, too, of gas from within the envelope—a disturbing influence which it may be impossible to prevent absolutely—will be another serious impediment to the successful preservation of this desired equilibrium.[1] All that need be here added, is that these and all other influences tending to disturb the balance of buoyancy must be guarded against as far as possible, and, when unavoidable, counteracted.

The means of maintaining this condition have been but little sought by aerial schemers; however, some of the contrivances which have been enumerated already in a former chapter,[2] as devised for the purpose of altering the equilibrium, would, so far as they are applicable to, or admissible for, that purpose, serve equally well for keeping it unaltered, and so are entitled to the credit of being suggestions for this end. Whatever objections, too, may be urged against them in the former case, are equally valid as regards their application to this latter requisite.

Our conclusion, then, with respect to the floatage will be, *that the envelope must be charged with gas in quantity exactly sufficient to counterpoise the weight of the air-craft, which must be provided with means of preserving its degree of buoyancy unaltered.*

[1] See p. 79. [2] See Chap. VI.

CHAPTER XI.

THE FIFTH DIFFICULTY—THE AIR-CRAFT—THE QUESTION OF LEVEL.

Let us now suppose that, according to the requisites we have ascertained our air-craft has its gas-vessel charged with hydrogen, so that the weight of the whole system is neutralised, and any force applied to it will make it move more or less. Let the envelope be impervious to the gas, of which too it will not be drained for varying its height in the air. Let our gas-vessel be firm to resist the air, long and narrow to slip through it, and stiff to retain its form when loaded. Finally, let the system be so put together, that when we have force to apply to it this force shall not derange its level position. Are these conditions sufficient to ensure steadiness and good working order in the craft? Though the propelling power may have no direct tendency to throw the system out of the horizontal set, will the craft be free from all tendency to take any other position? This is a most important consideration.

'Another fallacy,' says Colonel Maceroni,[1] 'in the idea connected with an elongated fish-like balloon, is also of a serious nature. How is it to be kept in a horizontal position? A balloon of such a shape (like Egg's, the Pall Mall gunsmith, or Col. Lennox's "Aerial Ship") being filled with gas, and sent up without any load, would certainly be liable to rise in any way but the one desired. If, to prevent its bursting by the expansion of the gas, it were only three-quarters or two-thirds full, it is ten to one but that it would rise up *endways*. If a net, car, &c., were to be attached to it with a load of passengers . . . . the

[1] 'Mech. Mag.' vol. xxv. p. 408.

gas would most likely rush to one end . . . . and it would go up endways, much to the inconvenience of the travellers in the car beneath.'

I have already had occasion to allude to this difficulty—if any mere obstacle which a man can face and determine to surmount should be called a difficulty—and to the contentment with which nearly all aeronautic projectors, since the time of Meusnier,[1] have consciously or unconsciously turned aside from encountering it, forgetting that man was to subdue the earth, not to be subdued by it. I find the law thus laid down by one of the earliest and most earnest advocates of aerial navigation, one too who brought a greater share of science and skill to bear upon the object of his enquiries than has often been the case with those who have followed him. 'Too great elongation (of the form of the gas-vessel) is bad. When the wind blows in gusts the gas-vessel advances with a speed different from that of the weight suspended from it; and this occasions swinging movements, like the pitching and rolling of ships. The machine then, dipping towards one end, the inflammable air, on account of its lightness, runs to the upper extremity. The longer the gas-vessel, the greater is the extent of this motion; and it will upset the air-craft altogether, if the burden which it carries does not bring it back to its proper position.'[2]

To avoid this, Meusnier goes on to limit the length of the gas-vessel to twice, or at most three times, its greatest thickness. If this were necessary, aerial navigation would be, as I have expressed my belief, unattainable. The liability of the gas-vessel to be deranged from its horizontal position is no doubt very much diminished by shortening its longer axis, by suspending the weight which it has to carry equally from all parts of its circumference, and by concentrating that weight as much as possible into a small compass, within which it is not subject to any shifting. When these conditions are adhered to, the horizontal position of the gas-vessel, with the boat hanging directly under

[1] See pp. 53, 86.

[2] Translated from a passage cited by Mongè ('Études,' p. 47), from 'Précis des travaux faits à l'Académie des Sciences de Paris pour la perfection des machines aérostatiques',' rédigé par le général Meusnier.'

its centre, is one of stable equilibrium for the whole system. The less the difference between the two horizontal dimensions of the gas-vessel, the more perfect is the stability. It is most complete in the case of the balloon and car. Such a system represents the pendulum of which the bob is the car, and the point of suspension is the centre of gravity of the air displaced by the balloon. But a long narrow gas-vessel floating level in the air may be likened to the beam of a balance poised upon an imaginary knife-edge, that passes horizontally through the centre of buoyancy, and at right angles to its greater axis. And when to such a gas-vessel a long boat is suspended, the whole system resembles a balance with scale-pans hanging from its ends and united together. The equilibrium of such an arrangement is liable to be disturbed by two kinds of changes: either by an alteration in the distribution of the floating agent within the envelope, or by a shifting of the weight in the boat. In either case the result would be analogous to a moving of the weight on the pans of the balance, so as to throw a greater share of it upon one end of the beam than upon the other.

Col. Maceroni probably had a correct conception of the condition in which the apparatus would be, but he expresses it erroneously. There would be no difficulty in compelling the fishoon to float horizontally. When once poised, which would soon be done by trial, it would remain so, and would have no tendency to rise in any other attitude unless the balance were disturbed. If the position of the gas within the envelopes, or of the ballast, or passengers in the boat, were changed, the equilibrium would be destroyed, and the system would now take a new position, which might be a fatal one. It is clear that the longer the gas-vessel and boat, the more sensitive will the system be to such disturbance. If all the weights in the boat be firmly fixed in their places, and if the gas be fixed in the gas-vessel (which can be the case only when the envelope is quite full), the equilibrium of the system will be stable, whatever the length of the two vessels may be—so far stable that no mere temporary change in the position of the craft itself will give it a tendency to take up a new attitude; it will return to its original position. Yet for every change in the arrangement of the load, however slight, a new position will be

assumed. But if the weights be free to move, and especially if the gas-vessel be not full, a mere pitch or oscillation of the vessel will give to the system a tendency to take a new position, in which all the gas shall get up towards the highest end of the gas-vessel, and all the load towards the lowest end of the man-vessel: in which unhappy state of things it will find a state of stable equilibrium. Now in a working air-craft the passengers cannot be all tied into their seats, and the gas-vessel cannot be kept always absolutely full. Therefore it will be in this state of unstable equilibrium, unless there be some special means provided to counteract the tendency to change of position. I have already noticed the kind of derangement that would ensue from enforcing a mere change of attitude on the system by an attempt to steer in a vertical plane.[1] It must be confessed, however, that the liability to this sort of upset is much less in the case of the old plan of suspension than it will be in the rational form which I shall have to recommend. But the liabilities are necessary, and must be met, which will be no difficult matter. With the usual form of connection between the two parts of the system, that by converging cords,[2] or by rigid framework, with the short boat below the eggoon, the equilibrium is similar to that of a balance-beam suspended by a cord with a single pan hanging directly below the point of support, and slung from both ends of the beam. The shorter the man-vessel is, and the farther it is placed below the gas-float, the more stable is the equilibrium. For the more the first condition is adhered to, the less room is there for shifting of the weight, and consequently for alteration of its bearing on the two ends of the support. (It is evident, of course, that the end nearest to which the weight is brought will be pulled down, so as to bring the centre of gravity under the centre of buoyancy; and that therefore, if the bearing of the weight on the two ends cannot be changed, the equilibrium cannot be disturbed by this cause.) Again, the farther the boat hangs below the gas, the farther any tilting force will have to raise the centre of gravity in producing its effect, and therefore the less power will it have to derange the system. Many people supposed Mr. Bell's oblong vessel would tend to rise up endways; this was a great mistake;

[1] See p. 43. [2] See p. 53.

the horizontal equilibrium of his system is quite stable, but this condition is ensured unfortunately by the very same arrangement which renders its propulsion impossible.[1] Indeed, with the ordinary mode of slinging the boat by converging cords, the gas-vessel, if stiff enough to bear the weight, might be of any length and narrowness whatever, and yet would not have the slightest tendency to, or even capability of bolting or plunging headforemost, skywards, or to earth, provided the boat were cramped to an exceeding brevity, and were hung sufficiently far below the gas. But, as has before been shown, such a system is absolutely unnavigable.

However, all this must be changed, and the power-vessel must be attached to the gas-float in such a manner as to enable it to be propelled. And, as will be seen hereafter, when this is the case the liability of the system to pitching will become a matter for very serious consideration. But that the stage of liability should be passed through, not in practice, but in the theoretical road to practice, is absolutely necessary, and it must not be shirked. I trust that I shall be able to show that the apparent difficulty will utterly vanish when fairly faced.[2]

However, though as I have said, apologising so far for the old contrivances, they have little to fear in this way: many of those who have paid attention to the subject have foreseen that if air-craft could be navigated, there would be a point here which would require to be dealt with. Accordingly we find some means devised for meeting the liabilities to loss of horizontality.

The equilibrium of position can be disturbed by two affec-

[1] See pp. 41–53.

[2] Ships are equally liable to this disturbance of the equilibrium if they are not properly ballasted. And the danger is greater with them than with air-craft, for if they pitch beyond a certain extent they must go to the bottom of the sea. But if an air-ship does pitch or soar head or stern foremost, it has a chance of righting itself, and is safe as soon as it can do so. Many a ship has been lost at sea by alteration of its balance, either by the ballast being shifted by agitation in a storm, or, in case of a soluble cargo, by its being dissolved out by water getting in. But neither of these agencies can affect the air-craft; and people still go fearlessly to sea in ships, notwithstanding them.

tions; either by shifting of the gas or of the burden. If the gas runs to one end, that end becomes the lightest, and if not prevented, rises; and if the weight is thrown towards one end of the boat, the opposite end of the gas-vessel, relieved from burden, is tilted up, while the heavy end of the boat falls in an equal degree, the centre of gravity remaining where it was if the gas, so far as its buoyancy is concerned, be in equilibrium with the air. Means, therefore, have been suggested for preventing or rectifying both of these modes of disturbance.

Meusnier, as I have mentioned, cuts the knot at once by making such a tub of the gas-vessel that it can no more be capsized than it can be propelled. And most of the inventors have followed him. But those who have either doubted the necessity of keeping the length of their vessel within such limits of brevity, or who have doubted the security of its equilibrium even with this precaution, have given hints, of which notice here follows, towards lessening the chance of upsetting it.

First, then, of the preventive means as respects the gas. It has been proposed to furnish the envelope with interior vertical partitions, which, by confining the gas to a certain portion of the length of the vessel, shall hinder it from accumulating at one end.[1] Now there are only two conditions which can set up this tendency of the gas to gather itself towards one end of the containing vessel. One of these disposing causes would be the tilting of the vessel itself out of the horizontal position, by any impulse upward or downward given to one end of either boat or craft, or by a sudden change in the distribution of the burden. If either of these occurrences took place, and the gas-vessel were not full, its contents would undoubtedly have a tendency to ex-

[1] See Mc Sweeny, 'Aer. Nav.' 2nd ed. p. 14; Sir G. Cayley, in 'Phil. Mag.' vol. l. p. 34.

I am not aware who first proposed this contrivance. There is some obscurity in the passage here referred to, in which Sir G. Cayley states its necessity. He does not explicitly say for what purpose the compartments are requisite. I presume, however, that the object sought is that which I have stated in the text, and for which it is certainly recommended by some of the projectors; for instance, by Mr. Mackintosh, in replying to Col. Maceroni, 'Mech. Mag.' vol. xxv. p. 463.

aggerate the derangement of the balance by pressing towards the upper end of the vessel. The other cause would be the sudden stoppage of the vessel when in rapid motion by any obstacle to its progress, such as by its rushing against a mountain side, or by its being suddenly checked by its anchor when carried onward by a wind. In such case the momentum of the gas would carry it forward to the head of the vessel, its motion being continued while that of the solid parts of the system was arrested.

Now I am not going to say that this device is not an excellent one; but I must remark, firstly, that no good pilot will either let his air-craft receive any impulse that can tend to twist it in any direction, nor will he let it run against a peak, nor let go his anchor in a gale, till he has got his head well up the wind, and is making all head against it with his propellers. If a bad pilot does allow either of these occurrences to take place (which of course will be the case sometimes), worse things will ensue than any diaphragms in the gas-vessel can prevent or mitigate. Secondly, that no good master of the man-vessel will permit the trim of his craft to be endangered by the shifting of his cargo; and that if, by ill-management, this does occur, it is the fault of the boat, not of the gas, and the boat ought to provide against its own contingencies. Thirdly, the less gas there is in the vessel, the greater will be the extent to which the gas can effect this inequality of buoyancy; and the gas-vessel will rarely be so large in proportion to its burden as to admit of its being charged to only a small fraction of its capacity; and the fuller it is, the less room will there be for this displacement. Fourthly, with that arrangement of the gas-vessel which, for other purposes, I believe to be necessary, and which I shall hereafter describe, the second cause of alteration of the bearing of the gas—that of the tendency of its momentum to carry it to the head of the envelope—would be rendered powerless. Fifthly, all that can be effected by this means will be ensured by other appliances, which must be adopted whether this one is resorted to or not, and of which likewise I shall give account in the proper place. However, so far as it goes, the notion is a good one, and not to be rejected.

Secondly, of the means of maintaining the balance as respects

the weight. The only useful contrivance which I have found mentioned of this kind is one to which I have already alluded, as being suggested for a means of steering in a vertical direction.[1] Indeed the end which, it seems, those who have proposed it had in view as its function, namely, that of throwing their air-craft *out of* the horizontal position on occasion, was exactly the opposite of that which we are now discussing. I have already shown that seeking to incline the vessel is a most fatal error in device. However, as the same instrument is as well adapted for maintaining the balance as it is for destroying it, and as those who have suggested it may have contemplated its use for the conservative purpose, I will here mention it, giving to them all credit for the contrivance.

Now by hanging a weight on the arm of a well-made balance, the beam may be made to set in any required position, the angle of its slant being determined by the distance from the supporting knife-edge of the point at which the weight is suspended. So it is obvious that just the angle which the axis of a gas-vessel floating in the air will make with the horizon may be settled by adjusting the position with respect to the centre of buoyancy of a weight which is attached to it. Of course, therefore, if the system should have any bias, inclining it to lie in a slanting position, this tendency may be neutralised, and the vessel may be compelled to take a true level set, by properly placing such a moveable weight. Dr. Polli proposed to have a weight slung on a cord between the boat and the head of the gas-vessel; by causing this to traverse forwards or backwards, the system may be placed, he says, 'in the inclination most favourable for the descent or ascent.'[2] The same notion is thrown out by Dr. McSweeny in an incoherent pamphlet, full of the oddest fancies about possible waltzes and polkas to be danced in the air by two balloons tied together, which he conceives would, if practicable, amount to aerial navigation. He proposes to adapt the shifting ballast to his crotchet (the pair of balloons) by running the weight along a cord from one to the other, forgetting that the weight even of the rope alone, without the addition of the hanging

[1] See p. 77. [2] 'Mech. Mag.' vol. xxxiii. p. 101.

ballast, would bring them banging together immediately, it it could be attached to them while they were 'at the same level, but at a distance.' What useful result would be obtained in his case from the sliding weight, if it were a possibility, is not apparent.[1] Finally, as I have before mentioned,[2] M. Mongé suggests the shifting ballast, 'pour incliner l'appareil.'

Now this sliding ballast is not only a good notion, but it is an appurtenance absolutely indispensable to the air-craft for maintaining its trim. Indeed the fact that those projectors who mention it, do so, as it were, by the way, as a thing perhaps to be adopted, not seeing that without it aerial navigation is an impossibility, is almost an evidence that they did not entertain a conception of its only legitimate purpose. However, a mere shifting weight is not sufficient. Although without it it would not be possible to keep the vessel long together in a horizontal set, it would not compensate and rectify any temporary bias which the system might receive, and which might throw it into a slant, and interrupt its steady progress. There must be a self-regulating apparatus, tending to keep the vessel horizontal, and to render the true level position one of stable equilibrium for the whole system. I have not yet seen any hint of such an adjustment for an aerial vessel. I hope to show in a future page how the air-craft may be made to keep its level by a self-acting equipoise.

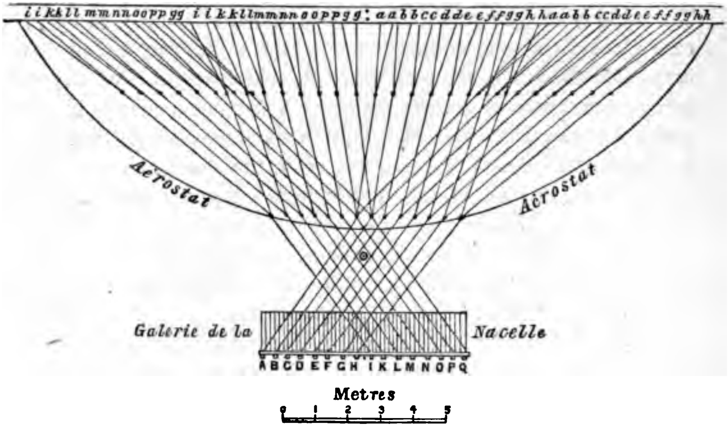
I have met with but one other attempt, or rather supposition, for it is no more, towards the solution of this problem of maintaining the level trim of the air-craft; this is M. Sanson's scheme of suspension. He thus describes it: 'Moyen spécial et nouveau de suspension, et d'équilibre horizontal indéstructible (trigonométrique) permettant aux voyageurs de se porter, isolement ou tous ensemble, sur n'importe quel point du plancher, sans danger aucun de faire chavirer la machine. Ce sont des cordes lesquelles portant des lambourdes sur lesquelles est posée la galerie, vont en se croisant, et après s'être bifurquées deux foix, s'attacher aux

[1] M'Sweeny, 'Aer. Nav.' 2nd ed. p. 29. There are in this production three useful pages (pp. 83, 4, 5), which contain a list of books on the subject of the author's fervid fancies.

[2] See p. 77; Mongè, 'Études,' p. 110.

équatoriales.'[1] Fortunately M. Sanson, to aid the reader in the conception of his design, represents it also by a drawing. His

Fig. 16.



method of slinging the 'gallery' (which would be represented by the boat of a real air-craft), differs from the ordinary system of conveying cords only in this, that the suspending lines are united in pairs, not each to the one next to it, but to the seventh in order of succession; and that the single cord which continues each pair, instead of being carried down to a corresponding part of the 'gallery' towards the same end, is attached to a point towards its opposite extremity. Thus by the crossing of these lines the ends of the 'gallery' are hung from the middle parts of the length of the gas-vessel, and the middle of the former from the ends of the latter; and each half of the gallery, as divided across the middle of its length, is suspended from the opposite half of the gas-float. How the contriver expects to derive from this arrangement the advantages he proclaims, I am at a loss to imagine. The most favourable result that can ensue is that the apparatus should behave as if it was all united into one rigid system, which under ordinary circumstances would be the case.

[1] Sanson, 'Nav. Atmosph.' p. 12, and cover, p. ii.

The worst effect would be, if the whole weight was thrown on the extreme cords at either end, for instance at the head, in which case the head of the 'gallery' would go down, and the head of the gas-vessel would be tilted up—like a shark gaping. The centre of gravity of the system must, of course, in every case place itself exactly under the centre of buoyancy, and this cannot be effected if the position of the chief weight, and therefore of the centre of gravity, be altered, without a change in the position of the whole system. With a short man-vessel like that in M. Sanson's sketch of his queer craft, the change in position arising from shifting of the weight would not be much, but it would be no greater with the common mode of suspension, which, as he proposes to propel from an equatorial framework round the gas-vessel, and not from the 'gallery,' would answer all the purposes of equilibrium for his system.

However, in aerial navigation neither system of suspension, the common or the Sansonian, will answer the purpose of preserving the horizontal equilibrium. Neither will any mode of suspension be of itself sufficient for this end, which, as I have shown, is absolutely necessary to be fulfilled.

It is therefore requisite, as another of the essential conditions of the art—

That the air-craft should be provided with means of maintaining both gas-vessel and man-vessel, as well as the propelling agent, in a horizontal position, and of readily restoring the system to a true level if the balance should be disturbed.

CHAPTER XII.

THE QUESTION OF POWER.

If, then, all that we have yet learned to be necessary can be accomplished, a likely-looking air-craft may be built, and may be made to float. But this is not all that we desire; it must be moved through the air, driven at a certain velocity. What speed must be attained I do not think it the least necessary to enquire at present. It is usual, with those who have considered this question with hopes of success, to acknowledge at starting on the one hand, that unless a certain amount of speed can be ensured, the experiment of locomotion in the air is not worth the making; and, on the other hand, that there is but little hope of attaining any considerable swiftness. Now I can make neither of these admissions. In the first place, I consider that a very slow motion secured in still air would be a most valuable step. And whatever wise people may say, I have no doubt that if an air-craft were constructed, which should be guided with certainty, in a perfectly calm atmosphere, to any given point, at any time, everybody would go to see it, and that everybody who was capable of being pleased with a human victory would be delighted, although its rate of motion might not exceed that of a brisk walking pace. On the other hand, I believe that when this is once done—and the less magnificent the beginnings, the more hopeful I should be for the end—improvements will gradually follow, and that no limit can be set to the velocity which we may expect to achieve in our passage through the air. Certainly no mode of locomotion of animals, vital or mechanical, can be compared for speed with that which I anticipate for human flight.

But force is requisite to produce motion, and motion through the air is opposed by the resistance of that fluid. And from experiments that have been made on bodies, of forms not suited for air-craft, as well as from theory, there is reason for believing that whatever may be the form of the vessels, the resistance of the air to their progress will increase as the speed increases, in ratios not differing very much from those of the squares of the velocities. The greater therefore the speed required, the greater must be the force supplied—greater according to this law—so that if a uniform force equal to one pound weight will move a given vessel at a speed of five miles an hour, it will require a force of about four pounds to drive it at ten miles, and of about four hundred pounds at one hundred miles per hour.

So, without any farther disquisition, our next condition may be thus announced. *The air-craft must be provided with a source of power sufficient to counterbalance the resistance of the atmosphere to the motion of the vessels, at any speed that may be required.*

Now there is really very little to report about the means that have been proposed hitherto for providing this power. The aerial projector usually, either—firstly, has shirked the question of power altogether, and has contented himself with planning mechanism; or secondly, has discovered some wonderful secret, which he will disclose on no account, but which is in fit season to do all the duty required of it; or thirdly, has suggested, as sources of force, devices that were utterly inadequate to the purpose, or were even in fact not sources of force at all; or fourthly, has relied upon means which were not practically available without so great a weight of appliances, as to render the scheme useless even on his own theory, except upon a scale of such huge bulk as to be an effectual barrier to its adoption as a first attempt; or fifthly, has fairly looked about him for the motive agent best suited by its lightness and energy for the required end. Besides these, a few good notions have been thrown out as bald hints, generally without any serious hope that anyone would take them up and work them out, which, of course, has never been done.

I shall give a few instances of the modes in which suggestions have been made, or not made, towards the end we are now considering.

Of the first class of powerless projects, some instances were exhibited in the Palace of Art in Hyde Park in 1851.

Of the second sort—of discreet silences—may be noticed an announcement, lately made in an Essay on Aeronautics, in the French newspaper 'L'Illustration,'[1] that M. Gavarni, the artist, had discovered a new power in nature, which was to solve off-hand the problem, amongst others, of aerial propulsion.

Of the third—the insufficiencies—M. Sanson supplies us with an example in his 'Agent moteur général (dynamo-mécanique) consistant en un homme agissant sur une manivelle.'[2] But the most absurd notion is that of M. le Baron Scott, who proposed for his motive power a pendulum, which, as it swings, should give a to-and-fro movement to a system of oars, connected with it by levers. He fondly imagined that, by increasing the weight of his pendulum bob he could ensure any amount of propelling power that he might desire;[3] quite forgetting that the pendulum would not lift itself; and that in falling it would give out no more force than was employed to raise it.

Of the fourth—the ponderous powers—the steam-engine is the type. Indeed there is scarcely any other that has been much thought of by the designers of aerial ships. M. Marey Mongè advocates the use of steam-engines for propelling air-craft; and endeavours to show, by comparing the sectional area of steam-vessels below the water-line, with the thickness of gas-vessels of cubic contents sufficient to lift the engines of the steamers, that taking into consideration the specific gravities of air and water, there is no reason why the same speed should not be obtained with the air-craft that is commonly maintained with the rapid river boats.[4] His mode of reasoning is a good one. However, his argument, notwithstanding the numbers and the calculations with which his pages abound, is very loose; for on the one hand he proposes that his gas-vessels should be cylinders of length equal to twice their diameter, and terminated by cones, of which each should have the same diameter for its length; forgetting that this form

[1] 'L'Illustr.' vol. xvi. pp. 86, 103 (1850, August 16, 23).

[2] Sanson, 'Nav. Atmosph. cover, p. 3.

[3] Scott, 'Aérost. Dirig.' pp. 72, 97.

[4] Mongè, 'Études,' pp. 117, 138.

would be far more unfavourable for eluding the resistance of the air than is that of the steam-boats as respects the resistance of the water. Again, he omits to consider the weight of the water in the engine-boiler, as well as the feed-water for supplying it; though he does reckon the coals for ten hours' consumption. On the other hand, he puts the case very unfavourably for himself, by taking the weight of the ship-engine, which he estimates at 1,000 kilogrammes, 2,200 pounds per horse power, as the standard for his aerial engines. This is of course enormously unfair for the air-craft, for no one would think of building such heavy machinery for purposes of flight. He appears not to contemplate the use of air-craft of less power than 40 horses, nor of less diameter than 52 metres, about 170 feet, with a length of 680 feet.

Sir George Cayley, who, however, seems equally to despair of our ever propelling gas-vessels of any moderate size, suggests the use of such steam-engines as those used by Mr. Goldsworthy Gurney, in his steam-carriages for common roads. He informs us[1] that these engines weigh only 200 pounds per horse power: to this of course is to be added the weight of fuel and water-charge—reckoned at 10 pounds of coke and 60 pounds of water per hour. The great objection, of course, to the use of steam as a motive agent for aerial navigation, is that the burden—however successfully the constant weight of the engine is reduced, and adjusted to the buoyancy of the gas-vessel—must be continually diminishing by the consumption of fuel and the evaporation of the water. This would be continually adding to the available lifting power of the gas, and disturbing the balance of floatage. If there were provision for condensing the steam, this would add of course very greatly to the load upon the gas. But Sir G. Cayley has not been contented to rely solely upon the steam-engine for success in propulsion. He is indeed almost the only instance of an inventor adopting the fifth method I have mentioned, that of seeking carefully for the most suitable power he could meet with. In his first paper on aerial navigation,[2] the very first

[1] 'Mech. Mag.' vol. xxvi. p. 422.

[2] 'Nicholson's Journ.' (1809), vol. xxiv. pp. 166–7; see also 'Phil. Mag.' vol. xlvii. p. 32[illegible].

subject which he treats is that of the power to be used for propulsion. He suggests the use of tubular boilers, not tubed boilers, like those of the locomotives, on account of their strength to resist pressure from within. He also speaks of an engine to be worked by the combustion of gas beneath a piston, and of a first mover in which oil of tar was the fuel, and which, though expensive in action, was extremely light. We find him again, in 1843, mentioning an engine to be worked by the expansion of atmospheric air as being well suited for aerial use.[1] He alludes also to gunpowder and condensed carbonic acid, as agents that might possibly serve the purpose. However, he rejects the first on account of its danger, and the second because it failed in the hands of Sir M. T. Brunel.

Of the other sources of power which I have found suggested the following are instances:—The explosion of a mixture of inflammable gas and atmospheric air; the gas to be abstracted from the float-reservoir.[2] Electro-magnetism, with an acknowledgment that enough was not known on the subject to give grounds for a decision as to its utility. Electro-magnetism was again suggested by a writer in the 'Westminster Review' who also recommended a trial of the explosive agency of gun-cotton for the purposes of aerial propulsion[3]—a very excellent notion.

It has been proposed to use the traction of flying birds trained for the purpose, as the motive force.[4] It is possible that this means may be resorted to as an occasional amusement in future days, when aerial navigation is accomplished by more practical methods. One of the quaintest projects, however, was that of M. Genet. He proposed to carry up horses, not dangling helplessly like M. Poitevin's, or with tiny hoofs strapped into the stocks like those of Mr. Green's pony, but harnessed to a rotary framework, in which they were to grind vigorously.[5] It is a pity he had not heard of the gentleman at Kirkcaldy who, as the newspapers recently informed us, was applying the power of mice to work machinery: they would be handy aloft, and are not

[1] 'Mech. Mag.' No. 1025, p. 265.
[2] Dœd Brit. 'Aer. Nav.' p. 8. Mason, 'Aeron.' p. 324.
[3] 'West. Rev.' 1848, January, vol. xlviii. p. 322.
[4] 'Mech. Mag.' vol. xxiv. pp. 57, 200.
[5] Delcourt, 'Manuel,' p. 144, and Pl. 7.

dainty in diet. The horse, however, will be spared this work no doubt, as he probably will be every other, when, as we progress, 'Knowledge comes, but wisdom lingers,' we shall substitute for animals of flesh, which we mutilate and torture, while they rob our poor human brothers of food—and resting or working, still consume it—others of metal, which will not grieve patiently at our unkindness, nor require food except when they are at work.

Human muscular power has of course been not only proposed, but tried again and again, not much in these latter years, but frequently in the early days of the balloon. It is, I believe, the only means of propulsion that ever has been actually applied to air-craft of any kind. The reasons of its failure I have already pointed out.[1] It has never had justice done to it by being used to the best advantage.

It appears, then, that no power has ever been applied in a good working form to air-craft; and that of the best suggestions that have been made, they have either been suited only to experiments on too large a scale for first trial, or else have been thrown out without any attempt to follow up the hint by showing how they might be made available in practice. It would seem that a general impression prevails that there are no motive agents at our command of sufficient energy to do the work we require of them in propelling air-craft of moderate dimensions. Thus the 'Revue des Deux Mondes,' in an article on this subject, winds up some very sensible remarks by confessing the orthodox faith of the man of science.[2] 'Personne n'ignore, qu'une foule d'ingénieurs et d'aéronautes ont essayé de mettre à exécution diverses combinaisons mécaniques propres à diriger les ballons. Toutes ces tentatives n'ont amené aucune espèce de résultat, et la pratique a renversé l'éspoir que certaines idées théoriques avaient pu faire admettre. L'on se fût épargné bien des mécomptes si l'on eût étudié d'avance avec les soins nécessaires toutes les conditions du problème. Les géomètres qui ont fait de nos jours une étude approfondie de cette question, sont arrivés à cette conclusion for-

[1] See p. 23, above.

[2] 'Rev. des Deux Mondes,' 'Les Aérostats et les aéronautes,' vol. viii. p. 238 (1850, Octobre).

melle. *Dans l'état actuel de nos connaissances et de nos ressources mécaniques, avec les seuls moteurs qui sont aujourd'hui à notre disposition, il est impossible de résoudre le problème de la direction des aérostats.'* The answer to this is simply that geometers are very good critics, but they are not poets.[1] I hope, in my Second Part, to be able to point out at least half-a-dozen means of power that will be efficient motors for the purposes of aerial navigation.

[1] The article Aeronautics, in the 'Encyclopædia Metropolitana,' flourishes off at the end with these words, in allusion to Sir G. Cayley, and to some prophetic lines, which he quotes from Darwin:—'For our own parts, we must confess that such flights of imagination seem to us to become poetry much better than philosophy.' Undoubtedly, but the learned Encyclopædist did not mean what he says. He evidently supposes that poetry means rhyming, and philosophy science, instead of respectively creation and the love of wisdom. It is as poets that we are to build palaces of art, tube-bridges, and air-craft. We may philosophise at the same time, but these works alone will not teach us wisdom.

CHAPTER XIII.

THE QUESTION OF WAFTAGE.

But the most energetic of powers will be useless to us, if we have not instruments for enabling it to act effectually upon the air, so as to impress upon it such motion, both as to velocity and as to direction, as may be required. We may, therefore, without further preface, state another of our requisites thus:

The air-craft must be furnished with appliances for transmitting to the atmosphere the force exerted within, so as to obtain a purchase for driving the system forward, and for modifying the direction of its progress.

Notwithstanding the neglect of the would-be navigators of the air to find power for the work they have taken in hand, they have been most busy in putting into varions shapes the instruments or intermediate agents of propulsion. The different means of taking the requisite hold upon the air, or of causing the forward pressure of the atmosphere upon the system to exceed the backward, may be arranged conveniently under three heads—as wings, wheels, and blasts.

The first class—the wings, wafts and oars—may be characterised as propellers of alternate action, and are in fact, elementary parts of some of the agents of the next class.

The second or revolving instruments may be sub-divided into two sorts, the direct and the obliquely acting vane-wheels. The first is a development of the direct-action wing; the second of the oblique or bird's wing, which latter, as a simple plane acting downwards, and partly backwards, is useless for the kind of flight in which the weight is supported by gas. But in its complex or rotary form, in which the downward action on one side

of the fulcrum is neutralised by the upward action on the other, the oblique waft is serviceable for direct propulsion.

There is another form of revolving agent, by which the second class passes into the third. This is the fan-blast, or centrifugal wheel, which does not act by its own impact direct or oblique upon the air, but by the formation of a stream or blast, of which the mode of action will be hereafter noticed. In the third class then, or that of blasts, I shall include this form of wheel.

Of the wings or oars a great variety were tried by the early aeronauts, with, it would appear, just enough of success to establish the point that a balloon could be moved, and to discourage any farther attempts to make use of them. The reasons of this failure have been already pointed out;[1] and may be briefly recapitulated thus—the improper mode of application of the force; the insufficient size of the wing surfaces; and the inadequate power applied to the levers, the men not knowing how to apply their strength in 'pulling.' M. Blanchard, who had been endeavouring to fly for some years before the first balloon went up, was the first to attempt to propel the great gas-globe with little oars or wafts. The destruction of his wings by the attack of a young student just as he was preparing to make his first ascent, did not discourage him from continuing his endeavours of this sort. They were, however, very feeble. I can find no account of the size of his rowing appendages; though from the pictures of his balloon, which may be found in all the Encyclopædias, it is evident that they were far too small to be of any effect; and from the arrangement represented, it is difficult to conceive how he could have worked them. There is no more information to be had as to the extent of Lunardi's wings; but the prints of his balloon and fittings show that they were absurdly diminutive. One of the best attempts of this kind that has been made was probably that conducted by Guyton de Morveau for the Academy of Dijon, in 1784. The balloon, which was a globe 27 feet in diameter, was furnished with a pair of oars attached to a hoop encircling its equator, from which they hung, so as to act in a

[1] See p. 34, above.

vertical plane; they were moved by a cord led down to the car. The blade-arm of these oars was 13 feet long, of which the wing plane occupied $11\frac{1}{2}$ feet, being of the form of an isosceles triangle, of which the base at the lower extremity was 50 inches broad, and of which the area was 24 square feet. There were also a pair of oars attached to the car, so as to be worked in a horizontal plane. The handle-arm of each of these was 2 feet, and the outboard arm, the whole of which was occupied by the blade, 7 feet long. The blade was an elliptical plane 4 feet broad; the area of the surface being about 25 square feet. These were to be feathered by turning round their long axes during the return stroke.[1] This is almost the only instance in which I find an account of the exact dimensions of the propelling apparatus used, being one of the very few trials of the sort that have been made by men who knew anything of the art of experimenting. Had Guyton de Morveau been living now, he, benefiting by the labours of others who have gone before us, would have framed his apparatus in a very different form. That such instruments must be utterly useless for any practical end in the propulsion of such a vessel as that to which they were fitted, requires no proof in the present day.

M. Salle proposed to propel the balloon by means of rectangular wing-frames or shutters of more likely dimensions; they were to be 18 feet long by 12 wide, with small panes of silk like the squares of glass in a window, each of which was to feather separately, as the shutters moved backwards to recover the stroke. He saw the necessity, not generally recognised by rowers either in the air or on the water, of counterpoising the weight of these large oar-blades;[2] but he designed to manage this in the quaintest way imaginable, by suspending each wing from a separate balloon of its own.[3] One great mistake which all the contrivers of such wings have made, is that of not learning to row a boat before they thought of pulling under a balloon. Had they taken this preliminary step, they would have learned what they had not sufficient theoretical knowledge to perceive, that to

[1] 'Descr. Aerost. Dijon,' pp. 141, 158, 162.

[2] See a letter by Mr. M'Gregor in 'Mech. Mag.' vol. lii. p. 351.

[3] Salle, 'Moyen Dirig. Aérost.' (1784), pp. 24, 33.

enable their oar-blade to get sufficient resistance from the water or air, it must be placed at the extremity of a very long arm, so as by increasing its arc of motion to exalt its velocity. Of course the varieties of oar-blade that have been proposed are very numerous, the chief characteristics on which the changes are rung being the open-and-shut, the feather by rotation of the axis, and the partial feather of separate small blades.

Mr. Bell [1] proposed an 'umbrella propeller,' which is nothing more than a shut-up oar-blade of the form described, caused to move in a straight line instead of in a circular arc by traversing on a guide rod.

But the most eccentric fancy of the kind is one of Dr. M'Sweeney's conceptions; he proposes to have two balloons tied together by a long rope (this is his crotchet), and make one pull the other towards it, so as to pass the first by its momentum, and so on, in a game of perpetual leap-frog. The head balloon is to arrange itself so as to offer greater resistance to the air than the advancing one. The contriver seems to have about half a notion that he is here only making one balloon the wing for the other. This 'alternate warping,' says the doctor, 'will do for aerial navigation what condensing in a vessel separate from the cylinder did for the steam-engine.' [2]

We next come to the system of wings or oar-blades arranged in a rotary form—as a paddle-wheel. It is quite evident at once that, unless each separate vane on the wheel is made to feather, or to change during each revolution the angle in which it lies with respect to any plane passing through the axis of the wheel, that their action, as respects the propulsion in one direction of a body attached to their axis, will be simply nothing, the forward motion on one side being counteracted by the backward motion on the other. I do not know that anyone can be convicted of actually proposing for an air-craft simple paddle-wheels such as are used by steamers, but the mistake is by no means too absurd for aerial schemers to have perpetrated. For many of them have been so far unable to see the difference between a vessel

[1] Specification. See p. 63, above.
[2] M'Sweeny 'Aer. Nav.' pp. 61-71.

entirely immersed in the air and one floating upon the surface of the water, as seriously to propose to apply fixed sails to the balloon for the purpose of directing its course.[1] The reader will conceive that such persons may easily have missed seeing that it is only not necessary that the paddle-wheels of a steamboat should feather its vanes completely, because the resistance they meet with from the air, in the upper part of their revolution is so small compared with that which the water offers to them below, that it may be considered as practically nothing: they may, therefore, have supposed that the same paddle which would answer in one case would do their work in the other. Besides, inventors are apt to make suggestions in a hurry. The following at any rate looks very like it:—'Il est à observer que les roues à palettes (ou l'hélice qui conviendra mieux pour la navigation aérienne) agissant dans un fluide 804 fois moins dense que l'eau, devront être établies de manière à avoir 804 fois plus de prise sur l'air que celles du Transatlantique n'en ont sur l'eau; ce qu'on obtiendra en augmentant simultanément la surface et la vitesse de ces palettes. Pour accroître la vitesse, il suffit d'augmenter le rayon des roues sans changer la vitesse, avec laquelle tourne l'arbre de la machine. . . . On raissonnerait de même s'il s'agissait d'une hélice au lieu de roues à palettes.'[2]

However, a feathering paddle-wheel for direct action has been

[1] See, for instance, 'Lond. Mag.' 1784, January, p. 13, and Henin, 'Mem. sur direct. aerost.' (An. x.).

[2] Mongè, 'Études,' p. 131. It is extremely unlikely that the steamer (the Magellan) with whose paddle-wheels (roues à palettes) the author is here comparing those of his supposed air-craft, were furnished with feathering-paddles, which till lately have very rarely been applied. He has evidently overlooked the error, though, from the way in which he mentions the screw propeller (l'hélice), he seems to have a suspicion that all is not right about the paddle-wheel for aerial propulsion. Besides, it must be remembered that the feathering necessary for a wing moving wholly in the air is a very different adjustment from that which answers the purpose required by a surface water-boat, and which is the only kind adopted in steamers. In the former case the position of the vane during its return stroke must be at right angles to that of its working stroke. In the latter case all that is ever required is that the vane should be kept at certain angles during the time it is in the water, that its stroke may be effective.

proposed. One of these is stated to have been made in model by M. Palmer very soon after the invention of the balloon.[1] Such an apparatus was also proposed in a clumsy useless form by M. Cappa in a paper read to the Academy of Sciences at Paris on January 14, 1784.[2] A similar arrangement was again suggested by M. Dauzel; it was to consist of four vanes arrayed about a central axis, so that each in turn should come into full play, presenting its front to the air in one part of the revolution and its edge only through the rest of the arc.[3] A writer in the 'Polytechnic Journal' proposes the same form of paddle-wheel for propelling an eggoon, and very aptly suggests that the best sort of feathering mechanism should be selected from the models in some Museum of Practical Science.[4] Another instance of this contrivance is Mr. Sadd's mode of propelling his twin gas-vessels already mentioned,[5] a model of which machine was exhibited in the Great Exhibition of 1851. This gentleman proposes to have two large wheels furnished with feathering vanes on this principle, and revolving on an axis, one on each side of the passengers' platform, between it and the gas-vessels.

The feathering paddle-wheel, notwithstanding its far greater economy of force, has been much less a favourite with the schemers than the oblique vane-wheel. This latter contrivance, in the various forms which it has assumed—from that of the separate windmill-sails on the one hand, to the complete-turn screw-propeller, miscalled Archimedean,[6] on the other, has been much affected by the inventors of aerial mechanism. The preference

[1] Bourgeois, 'Art. Vol.' p. 87.

[2] 'Lond. Mag.' June, 1784, p. 445.

[3] 'Phil. Mag.' vol. iii. p. 109.

[4] 'Polytech. Journ.' February, 1840, p. 138.

[5] See p. 46, above.

[6] The screw of Archimedes was almost as different a form of application of the same principle as can be imagined. It was an hydraulic machine consisting of an inclined plane wound round within a cylinder like a spiral staircase. It was not immersed in the water, but dipped into the liquid at its lower end. It could only work when inclined at certain angles. It lifted the water and discharged it at the top at intervals, once in each revolution of the shaft, when the end of the screw plane came to the lowest part of its orbit.

has probably been given to the latter in consequence of its simplicity and of its having no separately moving parts, which in the case of the feathering paddles entail some difficulty in construction, with of course some extra weight. With the rotary inclined plane, on the other hand, there is this disadvantage, that however cunningly the pitch of the screw may be chosen, there must be at every point of its surface a certain amount of force resolved in a direction at right angles to the line of motion, which force simply goes to oppose the revolution of the wheel, without setting up any resistance in the desired direction.

A very great number of persons have proposed, many have tried in model, and a few on the large scale, the oblique-vane-wheel, *l'hélice*, as the French call it, or screw-propeller; it is very difficult to say who first proposed it; most of those who have done so seem to have believed themselves the originators of the notion. One thing, however, seems pretty certain, that the screw-propeller was invented and used for aerial propulsion long before it was thought of for driving vessels by applying it to the water. The first mention I have found of its use is in a short account by M. Bourgeois of some experiments made by M. Vallet, of Javelle, to whom I have already had occasion to allude as having shown that a balloon might be made to move slowly in a given direction by means of oars.[1] He seems to have been a very industrious experimenter. The wheel of M. Vallet 'est composée de plans inclinés, qui frappent l'air sans interruption, et procurent la vitesse.'[2] M. Vallet tested the working of his device before applying it to a balloon, by trying it first in a boat, which, by its means, he navigated on the Seine, working the vanes, not in the water, but in the air. M. Bourgeois[2] states that M. Campmas had also constructed a propeller on the same principle. Blanchard, besides his wings, used to carry a kind of screw-propeller, which he calls a 'moulinet.' He had this with him on the occasion of his notable voyage on January 7, 1785, from Dover to Calais, but the only purpose it served was that of lightening his balloon when it came unpleasantly near the sea and would not rise—not by the rotation of the vanes,

[1] See p. 33, above. [2] Bourgeois, 'Art Vol.' 1784, p. 87.

but by being cast bodily away.[1] Dr. Potain, too, on the occasion of his attempt to cross St. George's Channel from Dublin, on June 17 of the same year, used a similar 'moulinet' of inclined vanes, as he declares, with some effect.[2] Sir G. Cayley in 1809 recommended a windmill-sail wheel for aerial propulsion, describing a toy model which anyone could make, and which would raise itself into the air, in illustration of the principle;[3] and in 1817 he again suggested the same rotary flyers for moving gas-vessels.[4] Mr. Monck Mason exhibited at the Adelaide Gallery in 1843 a model eggoon, which was driven by one oblique propeller formed of two half-turns of a screw plane arranged upon a single axis at the head of the car.[5] I have already mentioned

[1] Jeffries, 'Narrative,' p. 45.

[2] Potain, 'Relation Aérost.' p. 18. It has been stated that this gentleman did cross the sea on this occasion (Delcourt, 'Manuel,' p. 79). Historical sketches ought to be accurate, especially when the writer is treating of his own craft. The circumstance is utterly unimportant in the present instance, and is quite foreign to my subject; but no falsehood, however trivial, ought to pass uncontradicted if touched. The poor doctor failed miserably on this occasion, and was not only disappointed of the 'gloire' which he desired, and which his countryman (just quoted) wishes of course to claim for him, but fell out of his car and stunned himself, or fainted. at some place (in the county of Wicklow, some 35 miles from Dublin) of which to recover the name either into Irish or English from the French spelling I cannot attempt. It was two days before this experiment took place that Pilatre de Rozier lost his life in endeavouring to cross the straits from Calais to England. It is apparently the desire to point a coincidence that has misled the historian in this case. He ought, however, to have known better, for he says that Dr. Potain was a friend of his own, and the doctor's own account was not published till 1824, the very year in which M. Delcourt published his first productions about aeronautics.

[3] 'Nicholson's Journ.' vol. xxiv. p. .

[4] 'Phil. Mag.' vol. l. p. 35 and Pl. 1; see also 'Mech. Mag.' vol. xxvi. pp. 424, 426.

[5] Ellips. Ball. at Adel. Gall. pp. 5, 12; and 'Mech. Mag.' No. 1064, p. 468.

This model of Mr. Mason's performed so well that it gave rise to a hoax, that was extensively circulated in America, that this gentleman and some others, whose names were given with full particulars, had crossed the Atlantic in 75 hours, from a place in Wales to Charleston, U. S. Five columns of description of the voyage, with a print of the air-craft, an exact likeness

Mr. Green's experiments made in 1840, showing that a balloon could be made to rise and fall in the air by means of inclined rotary fan-blades.[1] Exactly the same contrivance was put forward, with the same view of seeking appropriate currents at different heights, by M. Van Hecke at Brussels in 1847; this gentleman brought his scheme before the Académie des Sciences of Paris; and, of course, the 'priority'—this mammon-idol of inventors—was immediately counter-claimed by another projector, M. Van Esschen, also of Brussels.[2] A host of other persons have proposed the screw-propeller for aerial navigation in one form or other; for instance, Mr. Evans in England in 1816;[3] Mr. Pennington in the United States;[4] Herr Leinberger of Nuremberg;[5] M. Jullien of Villejuif[6] in France. The person who most recently 'claims the application of impinging machines, constructed on the principle of the screw, or any modification of the same, as a propeller to a balloon,' is Mr. Bell.[7]

But a more recent device, which is certainly one of the funniest ever conceived, and which even Mr. Bell can scarcely have contemplated covering by his claim, is one which was hung up as a votive offering in the glass temple in Hyde Park. It is Mr. Luntley's 'Rotary Balloon;' the gas-vessel itself is to be its own screw-propeller; it is more like to a pig with a curly tail and a curly snout, or to a short slug with two periwinkles pulled out of their shells and clapped on one at each end, than to anything else. How the inventor intends to keep his car hanging to it while it is rotating, or to make it rotate while the car hangs from it, is very mysterious. This is probably the strangest vagary into which the human inventive faculty has strayed since it first went spinning with the balloon.

of the model, may be seen in the 'New York Weekly Sun' for April 20, 1844.

[1] See p. 75, above, and 'Mech. Mag.' vol. xxxii. p. 480.

[2] 'Comptes Rendus,' tom. xxiv. p. 68; Delcourt, 'Manuel,' pp. 264–273.

[3] 'Phil. Mag.' vol. xlvii. p. 431. [4] Wise, 'Syst. Aeron.' p. 84.

[5] Mongè, 'Études,' p. 109, referring to 'La Presse,' 1842, Août. 9.

[6] Turgan, 'Ballons,' p. 200.

[7] 'Patent Journ.' 1849, June 16, p. 94. See note, p. 63.

But, returning to the screw-vanes, I have not met with any account of experiments made for the purpose of ascertaining what was the best form of this instrument for work in aerial propulsion. It is probable that M. Vallet made some experiments of this nature in 1784; but whatever result he obtained would have been of little use as applied to a balloon, and therefore was not likely to be preserved. Experiments have been made with the water-screw to ascertain the best form for propelling ships; but even for this purpose it is probable that the truth has not been learned, for there are many different opinions now as to the best propeller, and many rival shapes claiming to be the proper one.[1] The best that has been done in the way of adapting the screw plane to aerial propulsion has been to take the form, which by one experimenter had been found to be the best of those he had tried, for work in water. This was done by Mr. Monck Mason,[2] who had the propeller for his model made under the direction of

[1] Inventions of this improvable kind, for the perfection of which numerous careful experiments are necessary to the end of learning something from nature by comparison of results, afford strong instances of the ill effect of competition in fettering the progress of scientific art. No individual can possibly make all the requisite experiments; each, therefore, struggling to beat his neighbour, makes either none at all, and jumps to a conclusion, or labours through as many as he can; always in a hurry lest some one else should be before him, and comes out with a certain result, of which all that can be said is, that it is probably better than he would have arrived at if he had tried none. Meanwhile, of course, the process by which he arrived at this result is carefully concealed, lest a hint and a lift should so be given to others, who, commencing with this advantage, might mount higher than the former patentee, in improvement. If these things were done by co-operation, for the common benefit, instead of for the personal aggrandisement of a few selves, what effects we should achieve! The progress of technical science would be one continual advance of steady development, instead of, as it is at present, a series of trips and blunders with a fortunate step taken every now and then. A line of continuous experiment in every branch of art would be ever at work, side by side with the application of the best of foregone acquirements. Every failure, every inferior form of appliance, that had been tried and rejected, would be recorded for the guidance of those whose talent it might be to spin the thread of progress.

[2] 'Ellips. ball. at Adel. Gall.' p. 11.

Mr. Smith, who had made some experiments towards improving the instrument for ship-use.

The questions, then, are still undetermined, What is the best form of screw-plane for driving air-craft? and What is the comparative value of such propeller as respects wing surfaces for direct waftage, weight for weight?

The next means of propulsion is the blast or jet. The mode of operation of this appliance is on this wise:—A stream of aeriform fluid rushing with velocity from an aperture or pipe-mouth causes the body from which it escapes to move in the opposite direction. The reason of the motion that ensues I shall not now enquire into. The methods of establishing the motor current may be considered under two heads, as the mechanical and the physical.

First, of the mechanical means. These are of several kinds; such as bellows, pumps, and revolving fans. As we have been discussing propeller wheels, the rotary fans will aptly follow them. The first suggestion of a revolving blower for this purpose that I remember to have met with is given by a correspondent of the 'Mechanic's Magazine' in 1836. 'I would have,' says Kenans, 'in the centre of the body a fan-blast or bellows, the vent being at the tail; . . . by working this, motion would result.[1] Again, Sir George Cayley says, 'Communicating centrifugal force to air by means of a hollow drum and fans worked by the steam-engine, is another means of getting a propelling power conveniently applicable in every direction that may be required; for by having a moveable mouthpiece from which the air escapes, the reaction will always be in the opposite direction. Though convenient in this respect,' he adds, 'it is too wasteful of power to be used for balloons, unless for small experimental purposes.'[2] Some very sensible remarks were made on the subject of propulsion, with a repetition of this suggestion of a fan-wheel, by Mr. W. Green.[3] Mr. Partridge, again, in the project published in the same excellent journal, proposed to combine two of the kinds of propeller-wheels. He would

[1] 'Mech. Mag.' vol. xxv. p. 158.
[2] 'Mech. Mag.' vol. xxvi. p. 427.
[3] 'Mech. Mag.' vol. xxxii. p. 517.

have one set to 'work on the spiral principle,' while the other were to be 'paddles or fanners, whose air-supply is received in the plane of the axis, and thrown out by the centrifugal action of the blades.'[1] The newspapers announced in the early part of last autumn that a monster air-craft, constructed by M. Montemayor at Madrid, was about to start from that city for London on October 15, and that the aeronaut confidently expected to make the passage in twelve hours. However, it came not. This machine was said to be furnished with two sorts of propelling agents. The one were wings for alternate action; the other was thus described:—'Sur le devant du navire aérien, et comme sur une proue, est placé un gigantesque tuyau qui, au moyen d'un mécanisme intérieur, absorbe une quantité considérable d'air, lequel, rejeté avec force par un autre tuyau placé derrière l'aérostat, lui imprime une impulsion extraordinaire.'[2] Whether the interior mechanism in this case was a fan-blower, a bellows, a pump, or a fancy of the reporter, I cannot say. The reader will please to take it as an instance of either sort.

Of bellows-propellers I need not add to Kenans' suggestion already quoted, any other instances, as the principle is the same in all these forms.

A pump to compress the air, which is to escape at the stern, is proposed by Mr. Lake in a paper to which I have already referred.[3]

Next, of the physical methods of producing a blast for reaction. The property of fluids that is involved in this is, of

[1] 'Mech. Mag.' No. 1032, p. 399. This Magazine, to which I have had to refer so often, is a perfect mine of information on every subject connected with mechanical contrivance. If any man invents anything, the first thing he should do is to sit down and run his eye through the indexes of the volumes of this journal. He will not have gone far before he will find his device described ready to his hand by some generous correspondent or fortunate patentee. One significant fact, however, is worthy of note, that he will find but few free suggestions or descriptions of open inventions in the later volumes, while the earlier volumes are full of them. In the present day almost everything is patented or kept secret, so hard runs the race for money.

[2] 'La Presse,' October 8, 1850.

[3] 'Mech. Mag.' vol. xxvi. p. 395.

course, that on which the flight of the rocket depends. There have not, therefore, been wanting inventors who have proposed to apply this principle to the propulsion of air-craft. Dr. McSweeny states that M. Le Normand put forth a plan in 1784 of propelling a balloon by jets of steam issuing from tubes on each side of its equator, in a direction at right angles to the diameter, the steam being conducted by pipes from a boiler in the car below.[1] Cavallo, in 1785, writes:—'It has been proposed to push against the air on one side of the balloon by means of the stream issuing out of an eolipile, in order to move the machine the opposite way. It has been proposed to produce the same effect by means of gunpowder; for instance, by rockets fastened to the machine, and fired so that their stream might be opposite to the course intended.'[2] The notion has not been forgotten in later days. Mr. Baddeley in 1838 stated that he had designed a balloon to be propelled by a rocket.[3] In a little periodical of popular science for 1841 there is a quaint rude print, with a suggestion by a Mr. Bilbrough, of the use of a steam boiler with a nozzle from which steam is to escape and 'by its counteraction against the air,' to propel the balloon.[4] The rough sketch there illustrating the equally vague notions of the designer, is the only drawing I have seen representing such a contrivance. I therefore mention it as I shall have something to say in another place on this matter.

The caudal appendage of locomotion—the rudder—has, of course, had its designers by hundreds. It would be quite superfluous to quote instances. Some have had two rudders, one for lateral, the other for vertical changes of course. Such was Baron Scott's plan.[5] Others have proposed a single plane, which, by rotating about a horizontal axis, might be made to act upwards or sideways. This form was adopted by Mr. Bell.[6] I have

[1] M'Sweeny, 'Aer. Nav.' p. 12. No authority is given, and I have not met with any more original account of the scheme.

[2] Cavallo, 'Hist. Aerost.' pp. 205, 293.

[3] 'Mech. Mag.' vol. xxix. p. 396.

[4] 'The Penny Mechanic and Chemist,' No. 259, p. 81

[5] Scott, 'Aérost. Dirig.' p. 83.

[6] 'Patent Journ,' June 16, 1849, p. 93.

already shown[1] that the vertical steerer tail is inadmissible. Some have even proposed to use the tail as a propeller, as the fish drives itself forward by the alternate action of the tail. Dr. Polli's scheme is an instance of this.[2] But all the rudders have been useless for steering of any kind, for never yet has air-craft had steerage way enough to render them available.

It is not a little remarkable that after the immense number of hints that have been given and attempts made (of which I have here made a meagre selection) towards getting the air-craft idea to stir, it obstinately remains stock still. The reasons, however, of its unliveliness have been already shown at several points in our enquiry, and need not therefore be here repeated.

[1] See p. 77, above. [2] 'Mech. Mag.' vol. xxxiii. p. 100.

CHAPTER XIV.

THE QUESTION OF ANCHORAGE.

If then we were provided with all the appliances of statical equilibrium, and with power, and propelling agents, we should be able to start and to travel through the air—at a certain pace. But let our speed be what it may, be exactly what we require, our object will not be fulfilled. We want to journey from a place—through the air—to a place; we have only as yet considered the objects of the first and second of these clauses. It will be of no use to us to be able to leave home, even with the velocity of lightning and with unruffled comfort, if we cannot make sure of arriving, on our voyage's end, at the spot to which we destined our passage. This, then, is a point fully as requisite to be secured as any other connected with our art. It is one, too, which has been almost entirely neglected by the contrivers of aerial transit. This may have arisen from two causes; firstly, from oversight, from failure to take a sufficiently comprehensive view of all the conditions of the problem; secondly, from want of resolution to face a difficulty, which the only experience yet brought to bear upon the subject shows to be great. Not only have the schemers generally failed to provide facilities for landing their passengers, but the objectors have not usually had the sagacity to perceive, that the termination of the journey by air at any required point, is a proceeding which, without some special contrivance which has never been suggested, would very frequently be impossible; and that if it were not invariably possible, the art, whose prospects they desire to demolish, would be utterly hopeless. I do not even remember to have seen this

difficulty urged against the progress of aeronautics by the most stiffnecked of the Encyclopædists.

It is quite obvious that even if any required place could be reached with certainty in all weathers, the attempt to land passengers from the air-craft during a gale of wind, at such spot, would often be a most perilous undertaking, unless some special contrivance for safety were resorted to, however well provided the man-vessel might be with anchors, or with means of propulsion. No one can have read a dozen newspaper accounts of balloon trips, without meeting with an instance or two of some difficulty in landing. The grapnel will sometimes be dragged along the ground for a mile or so before it gets a firm hold; and when it is secured, the balloon will sometimes be hurled about by the wind, plunging and rearing boisterously, before it is finally secured and brought to rest. This is sufficient to give a notion of the kind of difficulties that are to be encountered by the working air-craft. But the circumstances are by no means altogether the same with the two sorts of vehicles. The balloon has one advantage over the well-appointed gas-vessel in this position, while at the same time in another point it is far less fitted than the air-craft proper for security. On the one hand, the ballooner, by throwing away his gas, or as I believe he is wont significantly to express it, by 'crippling' his float-globe, soon relieves it from the pressure of the wind to which it is chiefly subjected by the bulk of its buoyant contents: this, of course, the aerial navigator will not do, for to keep his gas and to avoid 'crippling' his vessel will be his chief desire. On the other hand, the balloon, having no way of meeting the wind except that of yielding to it, is in a very different predicament from the air-craft that is provided more or less with the means of combating with the powers of the air, and of so choosing its position.

'La réputation des pilotes à former à la navigation aérienne dépendra particulièrement de leur habileté à exécuter les diverses manœuvres auxquelles ils pourront être nécessités pendant leur route . . . . soit pour prendre des inclinaisons . . . . soit pour savoir juger la hauteur . . . . soit enfin pour éviter les obstacles qui se trouveraient en arrivant à leur destination, lesquels

deviendraient également des écueils dangereux pour un pilote inexpérimenté.'[1] Thus one of the early schemers leaves his air-craft to get to land as best it may, trusting all to the hands of the pilot, and so I suppose have nearly all those who have followed him, with their suggestions and their models: at least there is neither any standard provision for this purpose, nor have the casual inventors thought it necessary to propose one. Mr. Monck Mason was the first author, so far as I am aware, who pointed out for the consideration of projectors the difficulties which attend aerial navigation in this respect. 'The whole air-craft,' says Mr. Mason,[2] 'must be so constructed as not to suffer from the shocks to which it will be unavoidably subjected whenever it comes in contact with the ground, owing to the impossibility of making the attachment to the earth with that degree of firmness and certainty which is necessary to ensure safety.' The only means of satisfying this condition that occurred to him, was that of building the whole apparatus sufficiently strong to avoid suffering detriment from the violence to which it will be exposed, and this he believed to be impossible to be accomplished, consistently with the lightness and extent of surface which are primary conditions of the structure. 'The disregard,' he adds, 'of this particular, constitutes one of the most remarkable characteristics of all the aerial projectors with whom I have ever communicated . . . . One of the adjuncts to the original plan of Count Lennox's air-ships was, I remember, a set of small wheels fastened beneath the car, in order to enable it to glide on the earth after the descent, and avoid the consequences of a too sudden interruption to its flight! The speculative Frenchman seems to have entertained a strange notion of the nature of the element with which he was about to contend, when in reply to the suggestion of a gentleman concerning the security of his machinery in the descent, he observed that it would be easy to obviate all danger upon that score by coming down under the lee of some building or high wall, by which he would at all times be sure of being properly sheltered from the wind; an ingenious expedient, as Mr. Green slyly observed, which might be considerably improved upon by

[1] Scott, 'Aerost. Dirig.' pp. 143–4.
[2] Mason, 'Aeron.' pp. 326–7.

the addition to his cargo of a ready made north wall, suited to all cases of emergency.'

However, to remove the opprobrium from the projectors, Dr. McSweeny[1] thus in his spasmodic style, settles the matter of landing. 'A rod extending horizontally from the car to break the force of a shock, should fit in a cylinder containing air. Several rods of this kind would save an aeronaut. I also suggested to have legs with pistons, fitting into cylinders containing air . . . . and barbed legs for a car to sink in the sod to prevent rebounding.' Again, 'to prevent concussion, there should be spiral legs at the bottom of the car. The car should be lined with air cushions. A long rope should hang from the car . . . . A hunting cap with springs would protect the head.'

If our heads are to require such protection as this, I do not think we shall make much of aerial navigation. It is possible that such spring buffers as the doctor recommends may be of some service in certain cases of accident, but they would be more cumbrous than useful in landing from air-craft. Mr. Mason's requisite indeed of brute resistance, is not the only alternative for the vessels. If they are to be liable to shocks on landing, by all means they must be stout enough to resist them. It is odd, however, that it seems not to have occurred to him nor to others who have considered our problem, that steam-ships do not run up high and dry on the shore when they have to land their passengers. Water-craft are not built strong enough to bear battering on the rocks in a storm: their way is to keep clear of them.

The only author whom I have found touching the question of anchorage with a view to its solution, in a manner at all reasonable, is M. Mongè, in his work to which I have so often referred. And the part of it which he treats relates solely to the conduct of the air-craft itself while at anchor, considered as an independent body floating in the air; he refers in no way to the coming to land, which is one chief point. He speaks thus:[2] 'La manœuvre des aérostats captifs par les grands vents est une question vitale pour l'aéronautique, question dont peu d'auteurs

[1] McSweeny, 'Aer. Nav.' 2nd ed. pp. 10, 17.
[2] Mongè, 'Études,' p. 144.

ont envisagé toute l'importance. Elle est cependant telle que, si elle n'était pas résolue un jour, il faudrait désespérer de voir l'aérostation sortir du rôle futile où elle végète; il faudrait renoncer à la voir servir non-seulement aux observations scientifiques de longue haleine, mais encore à la navigation aérienne. . . . Il faut que " the air-craft " puisse atterrer et rester à l'ancre soit à terre, soit à une certaine hauteur, partout où il le jugera convenable et sans avoir rien à craindre des grands vents; or il ne peut pas espérer trouver partout un abri contre ces derniers.'

M. Mongè goes on to remark that a gas-vessel may be anchored in a high wind under two conditions: 1st, that in which it is relieved of the weight of its boat by that part of the system being allowed to repose upon the ground; 2nd, that in which the whole air-craft is to be sustained in the air at a height.

In the first of these cases, says our author, the gas-vessel will have its whole rising power available for resisting the tendency of the wind to drive it to the earth. This had been pointed out before by Sir G. Cayley.[1] The same figure which served to illustrate his statements of the resolution of the forces acting on a gas-vessel propelled from the car, will equally exhibit the forces acting on it when anchored under a horizontal pressure from the wind. 'Let D B, fig. 7, page 48, be taken to represent the force of the wind, and C B the power of floatage; then A B will be the position the cordage will fall back to.' In the case of such a vessel as that which Sir G. Cayley was proposing, 'the resistance to the prow of the' gas-vessel in 'a hurricane of 60 miles per hour, would be about 20,000 lbs; deducting the car, then on the ground, its floatage would be about 63,000; so that it would fall back about one part in three . . . . so that permanently filled' gas-vessels 'would ride out storms when properly secured, without the danger of being driven to the earth and damaged.' Now this is a very essential point in the economy of air-craft, but it is but a small part of the requisites of our problem in respect of anchorage. It has in fact nothing to do with the navigation of the air, it relates only to the security of vessels out of service.

The second case, that of the gas-vessel anchored at a certain

[1] 'Mech. Mag.' vol xxvi. p. 426.

height with its boat appended, is one which it is not only even more important to meet, but which comes much closer to the question which we are now considering. For this M. Mongè endeavours to provide, and, as I have said, he is the only projector so far as I am aware, who has done so. He points out correctly the principle on which this is to be effected, but in the form in which he suggests its application, there would be some inconveniences attending the device. He shows that the property of the kite offers the true solution of this problem; and proposes to make the gas-vessel itself act the part of an inclined plane for the counteraction of the depressing effect of the wind. He further points out that there is yet a great difference between the conditions of equilibrium of an air-craft and those of a kite, stating, that, while the latter apparatus is urged downwards by the force of its weight, the former will be pressed upwards by the lifting of its gas.[1] This, however, cannot be accepted as generally true. In fact, the usual rule must be, as ascertained in our tenth chapter,[2] that the system will be in perfect equilibrium in the air, having no tendency either to rise or to fall. It is, however, impossible that this condition can be absolutely constant, although every endeavour must be made to maintain it: and it will be especially liable to variation when the vessel is at anchor; not lazily moored, but actively engaged in disembarking, and receiving passengers and cargo. It will therefore be quite necessary that the air-craft should be furnished with means of meeting the variations of buoyancy while at anchor in a wind. It will be necessary also to provide against changes in the velocity of the wind, and the consequent alterations of its pressure upwards as well as horizontally. These results can only be secured by varying the inclination of the kite-plane, which is to resolve the force of the wind in an upward direction. It would be extremely difficult to manage these alterations quickly, if the gas-vessel were to be the kite; the changes too in the inclination of the gas-vessel will with any mode of suspension that is at all likely to come into use, be accompanied with changes in the set of the man-vessel. Such alterations would be extremely inconvenient.

[1] Mongè, 'Études,' pp. 148, 151, 336.

[2] See p. 123, above.

Besides, even if no changes were necessary, if the air-craft was always when at anchor to be arranged at one certain angle with the horizon, this very derangement of the level although constant, would be attended with all the inconvenience which I have already pointed out in considering the horizontal equilibrium of the system[1] when floating freely in the air. M. Monge gives a very loose statement of the conditions affecting the position of the gas-vessel converted into a kite, taking no notice of the direct horizontal pressure of the wind on the bows of the gas-vessel, where but a very small fraction of the force can be resolved vertically, on account of the more unfavourable angle at which the surface is there presented to it. He leaves the question by stating that the angle at which the air-craft will have to be inclined, to enable the wind to lift it, will be very small, and will therefore cause no inconvenience to the passengers. The question is in fact one of some complexity, and depends for its solution on the form of the gas-vessel, according to the extent of under surface which it offers as available for the kite purpose, and to the extent of front which it will present in its inclined position to receive the direct drive of the wind. Further, even if such a form of gas-vessel as M. Mongè proposes and insists upon, were at all admissible, which I have shown that it is not, it would be very ineffective as a kite. For it would present below at best a cylindrical surface, and usually, according to his own impossible plan, one of sharp oval section,[3] not well suited for making the most of the resistance of the air, which in this condition is the effect required.

I conclude then that not even M. Mongè has offered a complete solution of this particular, of the requisites of anchorage.

And if this condition were so far answered; if the air-craft could anchor in safety at any desired spot; the problem is not yet satisfied. The passengers do not want to ride safely in the air till the gale is over, they want to land. I have not met with any notice of this requisite, or with any means proposed for

[1] See cap. xi., above. [2] 'Études,' p. 336.
[3] Mongè, 'Études,' pp. 56, 62, and figs. 6, 10.

fulfilling it. I have already alluded to the difficulties that will frequently attend its accomplishment in the ordinary way.

We may now sum up these final requisites of the journey's end, thus:—

The air-craft must be able to come to anchor in all weathers; to land and to receive cargo and passengers, and to ride securely at its moorings in calm air or in a gale of wind; without disturbance of its horizontal balance.

In my next part I shall endeavour to show how these ends may be effected.

[1] See pp. 167, 168, above.

CHAPTER XV.

CONCLUSION—SUMMARY OF CONDITIONS.

I BELIEVE that we have now arrived at a complete statement of the problem of aerial navigation; and that all the main conditions which are indispensable to its success, have been enunciated in the twelve propositions under which I have collected them. There are, of course, numerous minor requisites, which are either not peculiar to air-craft as distinct from other structures, or obvious at once on the first survey of the design. Such, for instance, are the propositions that the gas-envelope must not be liable to alteration by the action of the weather; that it must be protected as much as possible from exposure to injury by blows; that all the materials must be strong enough to do their work without breaking or giving way. To enumerate all such necessaries would be to trespass needlessly on the patience of the reader; many of them will of course be pointed out with their appropriate appliances in the succeeding pages of practical suggestions. There may, perhaps, be other requisites of detail which would not suggest themselves till one entered on the design of a complete vessel; these would at once meet with their solution from the hand of the engineer.

Before proceeding to consider at length the solution of the problem, it will be convenient to recapitulate the conditions which we have ascertained. In thus preparing them for treatment, as the subjects of the following part of my book, I shall arrange them in an order different from that in which I have introduced them already. In these preliminary considerations I have followed the method which seemed to me to be the most natural, leading on from point to point, as each difficulty would

be likely to present itself to the mind of a person approaching the subject from without. Having now, as it were, arrived in the middle of our ground, we can look around us and map it out in plan for the reception of such materials as we have in hand to build upon it.

The most appropriate mode of handling the practical part will be to arrange the matters in the order in which they would come before us in proceeding to test our theories by building an aerial vessel. I shall place, then, first the conditions respecting the construction of the air-craft, chiefly of the gas-vessel with which some of the main difficulties are concerned. These will be followed by the conditions relating to its statical equilibrium when connected with the other parts of a navigable system: the horizontal balance receiving the first consideration, and the floating agency coming next. Finally, the dynamical requisites of the motion of the craft will claim notice: the power on which the propulsion is to depend—the keystone, as it were, without which the rest of the edifice is useless, and of which the preparation has been commonly neglected by contrivers in this art—occupying the last place. I condense each proposition into a shorter form of words, as more convenient for repetition, and yet sufficiently expressing the conclusion which was before enunciated at greater length. The following, then, are the conditions of Aerial Navigation:—

1. The envelope must be gas-proof, light, and strong. (P. 109.)

2. The vessels must be of an elongated form—that of least resistance. (P. 97.)

3. The gas-vessel must be stiff, not bending under its load. (P. 55.)

4. The gas-vessel must be firm—not yielding to the pressure of the air. (P. 60.)

5. The envelope must be charged with the lightest gas that can be obtained. (P. 121.)

6. The vessels must be able to keep a level position when propelled through the air. (P. 51.)

7. The vessels must be able to keep a level position when floating freely. (P. 144.)

8. The vessels must be able to keep a level position when floating at anchor, and to land their passengers with safety. (P. 173.)

9. The buoyancy of the gas must exactly balance the weight of the craft. (P. 133.)

10. The craft must be able to rise and fall without waste of buoyancy or of weight. (P. 79.)

11. The craft must have means of taking purchase on the air for propulsion and direction. (P. 152.)

12. The craft must be provided with powers sufficient for its propulsion. (P. 146.)

Of this zodiac of requisites, the first, the second, the sixth, and the last, are the cardinal signs, of which these are the terms: BUOYANCY, SHAPE, LEVEL, POWER; and 'STABILITY' is the ecliptic on which they are strung, the character that stamps them all.

It may not be out of place here—before taking leave of the preliminary enunciation of the conditions of aerial navigation—to state the mode in which the essentials of the art have been laid down by former writers on the subject. I have already observed that the only recent authors who have examined the question in any detail, are Mr. Monck Mason, Sir George Cayley, and M. Marcy Mongè.[1] I shall here add the conditions as stated by these gentlemen, for the purpose of showing that I have not omitted to state any essential requisite that has before been pointed out; either by those who have despaired of success, of whose views those expressed in the 'Aeronautica' of the first of these authors may be taken as the type; or by those who, like the other two gentlemen, are full of hope for the results of experiment. According, then, to Mr. Mason:—

1st. 'The air-craft must be provided with the means of creating a reaction in the surrounding atmosphere, equivalent to the resistance it will have to encounter.'[2]

2nd. 'To put the machinery in motion a sufficient power is required.'[3]

[1] See p. 15, above.

[2] Mason, 'Aeron.' p. 306.

[3] Id. p. 316.

3rd. 'The gas-vessel must be of such a form as will admit of being guided.'[1]

4th. 'In the change of position which it will be forced to adopt when subjected to the action of a strong current of air, the air-craft must not interfere with the action of the machinery by which it is impelled.'[2]

5th. 'The materials must be strong enough for the work they will have to perform.'[3]

6th. 'The whole must be so constructed as not to suffer from the shocks to which it will be unavoidably subjected whenever it comes in contact with the ground.'[4]

7th. 'The agents of propulsion must be made to operate directly upon the body of the gas-vessel itself, and not upon the boat which is attached to it.'[5]

8th. 'The construction of the machinery must be such, that an injury to any one part shall not necessarily impede the action of the rest, or be attended with consequences involving the security of the air-craft.'[6]

9th. 'The whole must be so contrived as to maintain its equilibrium under all the variations of force to which it will be inevitably subjected in its progress.'[7]

Of these nine conditions the first, second, third, and ninth, correspond with four of those which have been laid down in these pages. The ninth is vaguely expressed, so that by simple interpretation of the words, which are those of the author quoted, it cannot be declared to be the same with either of our propositions. Two sorts of equilibrium are concerned in the air-craft: the one, that of buoyancy, which is no doubt that which is intended by Mr. Mason, for he devotes a chapter to its consideration under the general term of equilibrium; the other, that of level, to which no allusion is made, except partially and indirectly in the words of the seventh condition, as above arranged. Of the other five conditions which are not among those that I have formally enunciated, the fourth, the fifth, and the eighth, are obvious essentials, not peculiar to air-craft, but

[1] Mason, 'Aeron.' p. 325. [2] Id. p. 325.
[3] Id. p. 325. [4] Id. p. 326. [5] Id. p. 327.
[6] Id. p. 328. [7] Id. p. 328.

common to all constructions of moving mechanism, and therefore need not to be formally stated in treating this special branch of engineering; and the sixth and seventh are not true conditions of aerial architecture. For these are substituted in my system the conditions ascertained in the third, and in the eleventh chapters of my first part, and which form respectively the sixth and seventh conditions in the summary which I have given above. If I have not already made it clear why the air-craft need not be prepared for shocks against the ground on landing, nor be propelled by force applied to the gas-vessel, I should state, that there is no need that it should ever be struck against the ground; nor that the propellers should work anywhere but in the boat,—if the air-craft be properly equipped. It will be my business hereafter to show how this is to be done.

Setting off then these two errors against the four true propositions, and the three which, being indifferent, must not be counted, Mr. Mason may mark two for his statement of the problem.

The following conditions are Sir George Cayley's. I gather them from his paper on Aerial Navigation in the 'Mechanic's Magazine' for 1837. He does not enumerate the requisites as so many distinct propositions, but treats severally the points which I now enumerate.

1st. 'The gas-vessel must be filled with the lightest fluid possible — where a permanently buoyant gas is used, with hydrogen.' (Implied).[1]

2nd. 'The gas-vessel must be "perfectly air-tight, light, and strong."'[2]

3rd. 'To sustain the form of the "gas-vessel" when driven against the air with velocity, the gas must be condensed within so as to press rather more than the resistance of the external air.'[3]

4th. 'The gas-vessel must be of the form suited to meet the least resistance from the air, being for this purpose as long as can be managed without incurring weakness.'[4]

5th. 'The air-craft must be constructed "on that scale of

[1] 'Mech. Mag.' vol. xxvi. p. 420, note.
[2] Id. p. 419.
[3] Id. p. 419.
[4] Id. p. 420.

magnitude which a well-grounded calculation of their powers proves to be necessary." '[1]

6th. 'The air-craft must be provided with power sufficient to propel it.'[2]

7th. 'The power must be communicated to the air by an efficient apparatus for waftage.'[3]

All of these seven conditions are true requisites, except the third, which fails from not being sufficiently general. The object stated is essential, but the means insisted upon as necessary for fulfilling it are, as I have already endeavoured to show, inadmissible in practice.[4] The fifth of these, as stated in the author's own words, is a self-evident proposition, applicable to every mechanical construction; therefore not necessary to be specially insisted on here. But this remark does not apply to Sir George Cayley's meaning. He has printed the whole sentence in italics, giving to it an emphasis which he rests on no other in this whole essay. It is evident that he considers it of primary importance. The fact is that by the general term 'magnitude' he means 'huge size,' for he maintains that air-craft to be of any use at all must be of enormous dimensions. The gas-vessel which he proposes to have made for a first experiment, is to be 'thirty yards in diameter and three and a half times that measure in length.'[5] There is no doubt that if the data from which he starts his calculation are the most favourable that can be obtained, the result is correct; colossal bulk is an essential requisite of the structure. Now I cannot admit his data. The conditions which seem to bind him to immense size are the limit of proportional length to which he submits, which prevents him from diminishing the resistance of the air to any useful extent, and the quantity, and therefore the weight of the power which would be necessary to overcome the resistance. Besides, the bulk of his required floatage is perhaps still further increased by the motive power which he proposes not being the lightest possible. Some of my objects in writing this book are to show that we have no data on which any calculation of size can be grounded—to point out

[1] 'Mech. Mag.' vol. xxvi. p. 422.
[2] Id. p. 421.
[3] Id. p. 426.
[4] See p. 65, above.
[5] 'Mech. Mag.' vol. xxvi. p. 422.

what is necessary to be done for the ascertainment of these required data—and to show grounds for believing that vast size is not an essential requisite in air-craft. I therefore reject this proposition in its restricted sense as unproved, and omit it as unnecessary to be stated in its general acceptation. Five of the propositions which I have maintained are identical with the five of those that remain, excluding the third and fifth. Of my other seven, one, which forms the tenth in my list, namely, 'that the air-craft must be able to rise and fall quickly without loss of gas or ballast,' Sir George Cayley probably considered to be implied in his fifth and sixth. I think, however, that additional appliances are requisite for this purpose, and I have already stated my reasons for thinking so.[1] Another, my fourth, corresponds in object with this gentleman's third, rejecting, however, the principle which he considers necessary to be applied. The other five of my conditions, which I have placed as the third, fifth, sixth, seventh, and ninth in my arrangement, Sir George Cayley omits to consider. As to that which relates to 'stiffness,' he probably considered it hopeless to attempt to construct long gas-vessels with this quality; indeed, it is only the condition of great length, which I hold to be necessary, that renders the provision of stiffness one of difficulty, and consequently of primary import. I should rather say, perhaps, that though this gentleman has correctly stated his fourth condition as respects the form, that he deprives it of all its force by submitting to hard restrictions as respects length of figure, in his attempts to satisfy it. He thus escapes from the extreme necessity of contrivance which great length entails towards the fulfilment of this requisite; but, by thus limiting the scope of his devices, he, as it seems to me, fails in the solution of the problem. For I do not believe that, with vessels so short as those to which he confines his aspirations, any very useful speed through the air can ever be obtained. Of the remaining four conditions of my list, relating to the balance of level, and to the balance of buoyancy, Sir George Cayley seems to me not to have fully appreciated the importance, and for that reason not to have mentioned them. Five, then, is the number of Sir George Cayley's requisites which may be reckoned as sound.

[1] See Chap. VI. above.

The treatise of M. Marcy Mongè is arranged in a very orderly manner; he commences it by distinctly stating what he considers to be the conditions of the problem of aerial navigation, under nine distinct heads, and concludes the main part of it by recapitulating them.[1] The following are his conditions:—

1st. 'The gas-vessel must contain a gas easy of production and as light as possible.'

2nd. 'The gas-vessel must be completely unalterable by the air and impermeable by the gas.'

3rd. 'The gas-vessel must have an elongated form for cleaving the air.'

4th. 'The gas-vessel must have a certain pressure from within, so as not to be put out of shape by the resistance of the air when propelled, and so as to be able to resist the wind when captive or at anchor.'

5th. 'The air-craft must rise and fall without loss of gas.'

6th. 'The air-craft must be provided with a motive power sufficient to enable it to be navigated by means of propelling agents.'

7th. 'The air-craft must have a rudder.'

8th. 'The air-craft when at anchor or captive must have nothing to fear from high winds.'

9th. 'Gas-vessels of large dimensions must be easy of construction.'

Of these nine conditions all, except the fourth and the ninth, are included in seven of the dozen which I have adopted. There is, however, this difference in the two arrangements. I have thought it natural and convenient to separate the consideration of the propelling agents from the power that moves them, and to place them under the same head, as mechanical appendages, with the instruments of direction. M. Mongè places the power and the waftage together as one, and considers the rudder by itself. He quite destroys the value of another of these conditions by his treatment of it, though he expresses it correctly. For 'allongée,' which he correctly says the form of the gas-vessel must be, turns

[1] Mongè, 'Études,' pp. 8, 178. He states, in fact, twelve conditions; but the last three are merely headings to supplementary chapters, and not statements of requisites of the art: an error in distribution.

out to mean in his view 'of a length about three, or at most four times as great as the breadth of the figure;' and with these dimensions he proposes, for reasons which are simply absurd, a form which has nothing to recommend it. Indeed, his adherence to his notion of a 'cylindro-conic' gas-vessel utterly vitiates the whole superstructure of his scheme. This fairly deducts one from M. Mongè's points.

Of the remaining two conditions, the fourth is one which, as I have just had occasion to state, is true in general design but false in special principle; it corresponds in object with that which will be the fourth of my conditions. The ninth is simply a general truth common to all constructions;—all things that are to be made, must be easily made. It is only inserted by the author to give weight to his unhappy crotchet about 'dévelop-pable' surfaces. The statement of it seemed perhaps to be entailed upon him by the belief which he holds in common with Sir George Cayley, and, it must be admitted, with the other ablest writers on this subject—that enormous magnitude is necessary for air-craft to give them any chance of success. Twenty yards of breadth and forty of length is to be the measure of the first experimental machine which he proposes.[1] And he talks quite coolly of an 'aerostat colossal cylindro-conique' 140 yards in diameter and 560 yards in length. This author states propositions that correspond with eight of the twelve conditions we have arrived at, but of the chief part of one of the eight which he touches truly (the condition of anchorage), he is as silent as he is of the remaining four. The necessity, indeed, for three of these latter, those that respect the stiffness and the balance of level of the air-craft, would not be very urgent with such short vessels as he has in contemplation. I do not think M. Mongè can be allowed to count more than six for his ascertained requisites.

[1] Mongè, 'Études,' p. 174.

AERIAL NAVIGATION.

PART THE SECOND.

HINTS FOR THE SOLUTION OF THE PROBLEM.

'Possunt etiam fieri instrumenta volandi, ut homo sedens in medio instrumenti, revolvat aliquod ingenium, per quod alæ artificialiter compositæ aerem verberent ad modum avis volantis....Hoc instrumentum volandi non vidi, nec hominem qui vidisset cognovi, sed sapientem, qui hoc artificium excogitavit, explicite cognosco.'

Friar ROGER BACON, 'De Secretis Operibus artis et naturæ,' cap. iv. 'De instrumentis artificiosis mirabilibus.'

CHAPTER I.

INTRODUCTORY.

The object of this part of the book is to point out how the navigation of the air may be accomplished. The previous pages will have prepared the reader, if he has had patience for their perusal, for the matter which is now to follow. I may, however, briefly state what now remains for me to put before him. I have in the first part endeavoured to show, that though the propulsion through the air, at a rapid rate, of vehicles buoyed up by light gas, has not hitherto been accomplished, it has never been proved impossible. I have now, if I can, to establish the grounds of a belief that this achievement is possible with the simple aid of resources with which the present state of science provides us, and that without any difficulty, and without the necessity of making the first experiments on any scale of colossal magnitude. In the former part of my book I have stated the conditions which it was necessary to satisfy in any attempt to solve this problem. In this concluding part my task is to endeavour to show how these requisites may be fulfilled. I said in my preface that I am unable to give to my suggestions, as was my wish, the additional claim to attention which the results of experimental enquiry might put forth. I will not occupy more space by repeating the apology which I there gave in explanation of this. I trust that the number of experiments which will propose themselves under the several heads of this part of my book, will confirm what I said before of the impossibility of a single individual presenting the subject in a complete form. Indeed, I think it will be allowed that any contribution of a few experiments where such a number of details are required, would be

far less likely to impress a thinking mind with the possibility of the ultimate end to which they might remotely point, and to which they might be intended to lead,—far less likely, I say, than a body of suggestions founded on established facts, not only all converging to the same centre, but as a whole claiming to be sufficient for the perfect solution of the problem. Such a set of materials I have here to offer; not, perhaps, all shaped and smoothed and ready to be put together, but requiring, I believe, nothing but the finishing hand of the artificer to prepare them for arrangement into an organic whole, for whose completion they are sufficient without default of any element essential to the structure. I shall arrange my suggestions under separate heads corresponding to the conditions ascertained in the second part. Taking the conditions in the order in which I arranged them at the end of my former disquisition, I hope to show, for each of them severally, the means by which it may be satisfied. Finally, I shall endeavour to group together the results of this enquiry so as to show that none of the means suggested are incompatible with the use of the others, but that they will all work together for the fulfilment of their appointed end. I have no discoveries to announce, scarcely anything that may be called an invention to describe, none certainly to 'claim.' I have merely to point out the bearing of certain well-known principles in science, chemical, mechanical, and geometrical, upon the problem which it occurred to me to illustrate—principles whose application to this purpose seem to me to have been neglected by those who have gone before me, if indeed the general utility of one or two of them has not been entirely neglected by those who, in this Dædalic age, have been binding science to the service of man. The wide application, indeed, which some of the means to which I shall have occasion to advert, seem to me to have to numerous important purposes of everyday life on solid earth, are such as almost to stagger my faith in the correctness of my facts. Indeed, were there no other instances of our oversight and of our slowness even in this generation, to apply to our benefit all the natural powers at our command, I might be inclined to doubt whether the forces which I fancy I see close at hand are not mere fictions of my brain, and whether I have not been misled by some strange

economical fallacy in my reasoning upon certain data which I find in every manual of science. But I have before my eyes, in our oblivion of sewage manure, in our neglect of 15,000,000 acres of waste but cultivable land in our islands; and, in a greater marvel still, the idleness—forced or willing—of a fearfully large fraction of our population, poor and rich; other undeniable examples of yet vaster resources lying undeveloped at our feet. So I must say my say, and if I am wrong shall be ready to be rebuked.

If, then, I am led by the exuberance of my matter or by vagrancy of thought to touch on other matters collaterally, or indirectly connected with my main subject, I must beg the reader to pardon the digression if it offends him, or to take it as something added to his bargain if it should please him. What I have here to offer is for the most part entirely original, if not altogether new, in application. Where it is not original I shall be careful to say so, and shall cite the authority from whom I borrow or quote. And where I have found in the course of reading, since the growth of my own conceptions, that any notion or device coincident with my own has been thrown out or described before by any other writer, I have held it my duty (if in the former part of my book I have not already pointed it out) to make statement of the fact, with due reference to book and page. However, of the chief means on which I most rely for success, I have to my great surprise nowhere met with the smallest hint, in any of the writings on my subject that I have seen or heard of. Should I have failed in any case to assign to its real originator any piece of intellectual property of which he may be considered the owner by 'right of priority,' I must say that it has been from ignorance, and that the difficulty of finding all the required records must have deprived me here of the pleasure of making such acknowledgments. For a pleasure it is, indeed, to find that notwithstanding our absurd jealousies and competitions for wealth and fame, the mammons of the trader in art and of the trader in science, there is a law which binds us together as brothers in spite of ourselves in intellect, if not in feeling, so that it even seems to be impossible that any discovery or invention can be made by one man, that, if it has not been published or arrived at

before, is not about the same time revealed to some other person. Though, then, as I have said, all the chief devices which it is the object of the following pages to describe are original, I beg the reader to understand that I do not assert, for I do not believe, that any one of them are new. I believe that each and all of them, if they are worth anything, must have presented themselves to other minds besides my own, both before and simultaneously with their occurrence to myself. Others may not only have imagined, but have printed or spoken of the same combinations that I shall here suggest; if so, and I do not mention the fact, it will be unknown to me, not from want of enquiry, for I have read and listened to all I could find and hear upon the subject. Others again may have thought of these things, and may not have thought it their duty to publish or to mention them. This is the most likely case, and what I suppose to be the fact. If it be so, the only newness is that I have thought it worth while to print my thoughts; but there is not much novelty in such a circumstance as this.

'The thing that hath been, it is that which shall be; and that which is done, is that which shall be done: and there is no new thing under the sun.'

CHAPTER II.

THE SEVERAL MODES OF FLIGHT.

UNDER the general term 'Aerial Navigation by aid of buoyant gas,' I design to include the whole art and method of travelling through the air on this principle, on any scale of application. Now the manner of accomplishing this will depend to some extent on the complexity of the apparatus made use of. This admits of some differences, which are such that the mode of practice may be divided into several kinds or degrees. There are three manners of locomotion available to man, corresponding to the three dimensions of space, to the three orders of matter, solid, liquid, fluid, and to the three correlative orders of animal life, the earthy, the watery, the airy.[1] Progression through the air may be likened in this respect to movement upon the land or upon the water. The varieties in each of these cases may be arranged in order according to the nature of the instruments employed, commencing with the simplest.

It is probable that the art of aquatic locomotion has gradually grown from its elementary condition up to the advanced state in which it is at the present day. With land-travelling the order of development has not been quite the same. The simplest sort of motion at the surface of the water is that of swimming, in which a man propels himself by the exercise of his own limbs, without the use of any seat or vessel for the reception of his person. It would scarcely be any complication of this easy method if he took to himself a log of light wood to assist his lungs in buoying him upon the liquid. Even the swimming-stockings, with their bird's-foot web, which have been lately tried, might have been

[1] See page 130.

invented by an uncultivated islander. Perhaps they were, ages ago. The second step would be that of making a canoe, sitting in it, and propelling it by paddles, which would soon become converted into oars, working on a rowlock or thole-pin. A very untutored mind would soon discover the benefit of Association in this matter; and perhaps it would require a very clever and learned one to find a better illustration of this principle, which the old man taught his sons with the bundle of sticks. If Fourier had been an English islander instead of a Continental bagman, he would have taken an eight-oared racing-boat, instead of a phalanx, as his symbol of co-operative power. In the boat the resistance to its rapid progress is not at all increased, but diminished, by increasing its length, and but slightly increased by the additional weight of more rowers, which causes it to sink a little deeper into the water. While, on the other hand, every pair of arms that can be set to work will add with their whole power to the speed of the canoe. Wild men of the South Sea must soon have found out that they could go faster over the waves by joint efforts in one boat than they could each labouring by himself in a solitary skiff. This, then, was the third mode of water-travelling. The fourth step in the navigation of the waters was the substitution of the brute powers of nature for human strength: first wind, then horse, then steam. And here is the art in its present state; though as yet, perhaps, only on the threshold of this last stage.

Similarly on land, men walk, propel themselves by manual labour, each in his own velocipede, or by joint exertion in a wheel-carriage in which several can work the cranks at once. Again, they can be driven by machinery, of animal or of iron, on roads macadamised or of iron, or on no roads at all. In land locomotion we have done but little in the second and third modes of propulsion, and we have yet a good deal to learn in the last.

Now I wish to point out that aerial transit admits of four chief varieties in method, which are analogous respectively to the four sorts of motion upon the water. In this classification of them I take man as the centre of arrangement, considering the gas-vessel and propellers as appendages to his person. I shall,

hereafter, have occasion to take them in a somewhat different order, treating the air-craft as itself an organic structure, of which the motive agent, which may, or may not, be man, is a special part.

The first mode of progression through the air is that of flying, in which a man, without any vehicle to hold his person, may propel himself by wings. In the mode of practice which I have undertaken to advocate, his condition will be analogous to that of a person floating with a log of wood or with corks in the water, and urging himself forward by his limbs with the aid of swimming-stockings. Next, he may row himself either alone or co-operatively. Lastly, he may get himself propelled by artificial power, with aid of appropriate machinery.[1]

Bishop Wilkins, I find, arranges the modes of flying under four separate heads, not, however, corresponding exactly with my divisions. He is really worth quoting.

'There are four several ways whereby this flying in the air hath been or may be attempted. Two of them by the strength of other things, and two of them by our own strength. 1. By spirits or angels. 2. By the help of fowls. 3. By wings fastened immediately to the body. 4. By a flying chariot.

Having discussed the first three methods, concerning the third of which I have cited his judgment in a former page,[2] he thus treats the fourth, summing up in favour of the plan of human co-operation.

'But the fourth and last way seems unto me altogether as probable, and much more useful than any of the rest. And that is by a flying chariot, which may be so contrived as to carry a man within it; and though the strength of a spring might, perhaps, be serviceable for the motion of this engine, yet it were better to have it assisted by the labour of some intelligent mover,

[1] These, however, are but analogies, not close resemblances, for the conditions of a body floating in the air are very different from those of one floating on the water. A closer relation will one day be established between aerial and aquatic locomotion, when men, having learned the true art of propulsion in the air, will apply its principles to kindred practice in submarine navigation.

[2] See page 18, above.

as the heavenly orbs are supposed to be turned. And therefore if it were made big enough to carry sundry persons together, then each of them in their several turns might successively labour in the causing of this motion; which thereby would be much more constant and lasting than it could otherwise be, if it did wholly depend on the strength of the same person. This contrivance being as much to be preferred before any of the other, as swimming in a ship before swimming in the water.'[1] The author then devotes a whole chapter to 'A resolution of the two chief difficulties that seem to oppose the possibility of a flying chariot.'

But I must return, for I have the same work in hand, with this disadvantage, that I find twelve difficulties to be resolved, and must give a chapter to each. I shall endeavour, then, to show how each of the modes of aerial locomotion which I have mentioned (not the bishop's 'four ways' but my own) should and may be effectually carried out. The first part of my task has been to ascertain the conditions that are necessary to be attended to in the practice of this art. The more complex mode of application includes among its main requisites all the essentials of the more simple; I shall, therefore, in providing for the general necessities of the subject, confine my remarks chiefly to the ultimate aim of propelling through the air, by means of mechanical power, buoyant vessels suited for carrying several passengers. In determining the requisites of this problem some points will have to be insisted on which will have no application to the case of solitary flying. I shall make the necessary limitations where I may have occasion to do so, in the course of my endeavours to show the practical solution of the difficulties ascertained in the first part. It will be understood, however, that in the second or practical part, the suggestions I shall make will bear chiefly upon the solution of the problem in its most advanced phase, that which may be called aerial navigation proper. When I have to refer to the lower degrees of function, and to organisms simpler than the well-appointed air-craft, I shall clearly mark the special reference.[2]

[1] Wilkins, 'Math. Mag.; Dædalus,' c. vii.

[2] It is worth remarking (as a hint to mankind that they ought to navigate the air) that all the chief divisions of the animal kingdom, classes as

Generally the main differences in application resolve themselves into two, namely, those of simple flying and of propelling

as well as orders, according to their nobility, have sent up representatives, as it were, into the air to fly. These are clearly examples for man, the microcosm, of what it is his business to do. The lowest animal forms are distinctly aquatic. Water is the fountain of all animal life. 'Let the waters bring forth abundantly the moving creature that hath life,' Genesis i. 20. (See page 286, below; and 'Sequel to Vestiges of Natural History of Creation,' p. 70, where a hint of this law is given; where, however, the author does not seem to perceive of how mighty a truth he was treading on the threshold.) So not only do gnats and toads spend their first life in the ponds, and the silliest birds live about the sea, but every bird that flies and thing that creeps has its birth in the liquid egg. It cannot be expected, then, that the least developed animals, the typical water creatures, should fly. So the great aquatic class, which I take to include all the living creatures except the Articulata and the Vertebrata, namely, the Acrita, Nematoneura, and Mollusca, do not fly, but keep almost exclusively to their proper liquid sphere. But the articulated creatures, which I believe to be the real aerial order, send forth from among them the countless host of insects to do their duty in navigating the air. (The author of the 'Theory of Life,' S. T. Coleridge, throws out a notion that insects are not to be included in the animal kingdom, but that they have a separate dignity of their own (pp. 59, 74). This fancy evidently, like many other incorrect ones in that posthumous work of the great philosopher, is the offspring of an incomplete survey of the subject treated of.) The vertebrated order, which, being the highest, includes representatives of all the others, has not only a special class, the birds, as a distinct aerial type, but has a flying group in each of the other classes. The aquatic class, with its three family types, the fishes, the frogs, and the lizards, once made vigorous efforts, by the last of these groups, at aerial navigation.

The little 'flying fish' is just an indication of an aerial attempt in the lowest circle. I believe the ambition of the amphibia has not led them farther skyward than the climbing of the tree-frog has proceeded. But the other family, the huge reptiles that held the throne of the earth before the great empire of the mammals came and conquered, and which swayed, by its crocodiles and fish-lizards, the provinces since ruled by the whales and the cats, governed the air by its armies of wing-fingered harpies. However, 'the great dragon was cast out,' and the word went forth to the serpent, 'upon thy belly shalt thou go.' So the reptile dynasty fell, and was no more 'the spirit of the power of the air.' And now came the birds and the beasts, the airy and earthly types, to hold the divided empire, as the power of life was developed in this direction from the fluid to the solid. But the birds were not to have the whole air to themselves. The law of

a boat or man-vessel. The distinctions to be drawn between the requisites in the three cases, which, as I have pointed out, are included in the latter class, are but few, and are generally only simplifications in favour of the craft driven by human power.

There are, again, two cases in the general description of vessels buoyed up by light gas. The floating agent may either be a gas permanently lighter than common air, or it may be one such as the atmospheric fluid itself, which requires heat for the maintenance of its levity. These two forms of the lifting power will involve differences in the construction of the craft, especially of the gas-vessels. I have, however, chiefly in view the use of hydrogen as the source of buoyancy. I shall, therefore, generally describe such appliances as are suited to vessels charged with this gas. When, on occasion, I have to provide for the convenience of hot-air vessels, I shall make special mention of the object under consideration.

concentration of function (p. 287) is not the only order of nature, so the sojourners on the dry land still keep their bats fluttering in the air, and echoing the message which the birds, even the silent ones, are preaching to man, 'Come and do thou likewise; the dove has expelled the serpent from the air, the heaven is now thine.'

CHAPTER III.

CONDITION 1.—THE ENVELOPE MUST BE GAS-PROOF, LIGHT, AND STRONG.

In laying down the road to the accomplishment of our art, there are two sorts of experiments necessary to be undertaken. The first concerns the preliminary selection and preparation of materials and of forms for future construction. The second relates to the fitting of these together, and testing their behaviour in practice, commencing, of course, with trials on the smallest working scale. Our first condition is a subject for experiments of the former nature. And a great number of them it will require before perfection in this matter is reached. It is fortunate that absolute imperviousness to gas will not be quite essential in the first experiments of the second order. For flights of some length may be taken, without much inconvenience arising from a certain amount of leakage; indeed, until the necessary security is obtained for the gas, it must be allowable to carry ballast, which, by its gradual rejection, may compensate for losses of buoyancy. Voyages of some length may be thus achieved; but, meantime, every endeavour must be made to acquire the means of making envelopes absolutely gas-proof.

I have not much to offer on this head, beyond a few hints for experiments. Imperviousness, lightness, strength, are the three requisites in an envelope material. The appliances for testing it as to the two latter points are, of course, simple enough, the balance and weights.

In ascertaining the weight of a texture, if only small samples are to be had, several different pieces cut to a certain dimension—an inch square will be sufficient—should be weighed in a gcod

balance. The mean of their weights will give the correct value in this respect of the material, if its texture is at all uniform; and if not, it will not be suitable for our purpose. For convenience of comparison the weights of the different specimens should be referred to a standard unit of square measure, and entered in a table. I subjoin the weights of a few materials, which I ascertained with the view of learning their suitability in this respect for gas-envelopes.[1]

With respect to the strength or capability of the material to resist strains tending to rend it, Sir George Cayley's method of rolling a given breadth of it up into a rope,[2] and hanging weights to it till rupture ensues, is probably, if carefully executed, as good as any that can be devised.

It is of course not necessary to build a huge gas vessel, and try how long it will lift its load, for the purpose of ascertaining the retentiveness of any stuff. It is not even necessary to make a bag which, when filled with hydrogen, will float by itself. However, if plenty of material is at hand, and gas can be had readily, this plan is very useful; and the mode in which I recommend that the material should be tested is the following:—

Let a chain be prepared, of which the links have been ascertained, by previous weighing, to be as nearly as possible all of the same weight. Such a chain is most readily made by cutting metal wire with a pair of shears into pieces of the same length carefully measured off; these, when properly bent, will form the links. Of course the links may be reduced to the same weight to any degree of accuracy by filing them; and it will be very convenient if the wire can be so bent as that the links should be of exactly the same length, so that any measured length of the chain shall indicate a certain weight. The smaller the scale on which the experiment is to be tried the greater the accuracy requisite. I have used for this purpose pieces of common brass clock-chain, and have been surprised to find—by weighing first several of the links separately, and then lengths of several links from different parts of the chain—the weight of the links uniform to a grain. If now a balloon made large enough for the purpose of the material

[1] See Appendix B. [2] 'Mech. Mag.' vol. xxvi. p. 419.

to be tested is nearly filled with hydrogen, and loaded by having one end of the chain attached to it, it will lift of the links a certain number, so that the height at which the balloon stands will exactly indicate the weight raised and the degree of buoyancy of the balloon. As the gas escapes the balloon will deposit the links of the chain; and if the length of the links be uniform, the retentiveness of the envelope may be at once learned by two simple measures—of length and of time. The longer the time during which the balloon will float at its original height the better the material. Again, the specific gravity of the gas being known, the quantity of it that has leaked out may be at once learnt from the number of links set down.

But to make a balloon that will float, and lift a small weight, requires a considerable extent of some materials, particularly of such as are most likely to be of use in large air-craft, which cannot be of gossamer lightness. The retentiveness of the stuff may, however, be tested quite as readily with a very small quantity; a couple of square feet will be ample for the purpose.

Let a small bag be made of the material to be tested. It is not necessary that it should be made spherical by means of gores with several seams. Two circular or even square pieces sewn together at the edges, with a small neck for the introduction of the gas, will answer every purpose. All that is necessary is that the seams should be completely gas-tight, that the neck should admit of being perfectly closed, and that the bag, when charged with gas, should not be thrown into such folds by its swelling that the stuff should be liable to crack or to be otherwise injured. Let, now, the test chain, prepared as before described, be suspended from the end of one arm of a long light rod, poised for a balance beam,[1]

[1] The rod must not be poised exactly as an ordinary scale-beam. It must be balanced on an axis passing *through* its centre of gravity, not *above* that point, as is necessary with the usual weighing apparatus. In the case of the latter instrument one of the objects sought is, that the horizontal position should be one of stable equilibrium for the beam, so that the farther it is displaced from a true level set, the more force shall be required to move it. In our testing balance the beam must be in equilibrium in every position, so that it shall require the same force to lift each successive link of the chain as it is called upon to rise by the descending counterpoise.

and the bag, filled with air, or at least containing no other gas, from the other. The number of links lifted by the weight of the bag having been noted, let it now be charged with hydrogen and again attached to the beam; the difference between the less number of links now lifted, and the number drawn up before, by the other end of the beam, will indicate the buoyancy, and therefore the quantity, of the gas introduced. The apparatus being now left to itself, as the gas escapes the bag will become apparently heavier, and, falling, will lift in succession the links of the chain till, if the gas all escapes, it has raised as many as were sufficient to counterpoise the empty bag. If the bag is quite impervious, the beam will of course remain in its original position of equilibrium.

Of course the same result will be equally obtained, if it should be more convenient, by weighing the bag from time to time, in the usual manner, with a common balance: and if all that is desired is to ascertain, by a single comparison, whether the material is gas-tight or not, the use of a pair of scales will be the simplest operation. But the method which I have proposed has the advantage of enabling a continuous experiment to be conducted, and the results to be seen by mere inspection at any time. Care, of course, should be taken that the apparatus remains of nearly the same temperature. As absolutely accurate results are not required, extreme precautions need not be taken, nor corrections for temperature introduced.

Vulcanised caoutchouc sheet has these advantages and disadvantages as an envelope material: [1]

The chain will have to be adjusted from time to time, so as to hang vertically, for as the end of the beam-arm does not rise in a straight line, but in a circular arc, the chain will not hang straight down unless previously disposed for that purpose on the support on which its lower end rests. It will, of course, be convenient, in setting the apparatus in the first instance, to arrange the beam either in a horizontal position or dipping towards the chain end, so as to allow scope for that arm to rise. This will be managed by raising or lowering the support on which the lower end of the chain rests, or by adjusting the length to a fine cord by which it must be hung from the extremity of the arm. The arms must, of course, be of precisely the same length.

[1] See Appendix C.

When made-up into vessels, every part of it is united into one substance at the joints; there are no seams which may require special attention. When sufficiently thick it is probably as air-tight as any material that can be made, and it can be had of almost any thickness that may be desired. Its elasticity will enable it to dilate to some extent with the expansion of the gas, and so not suffer it to escape so soon. I do not believe, however, that this is a very useful quality. It is not easily torn or perforated by a blow; its elasticity serves a good end in this very important matter. The same quality allows it to be rolled and squeezed without any injury to its texture. And when no longer faithful for the purpose for which it was made up, the material will probably be available for other uses.

On the other hand it is a very heavy substance. When once perforated, the holes, which would probably be rather difficult to discover, cannot be stopped so that the patch shall be of one substance with the original membrane; it can only be mended by a piece of the same stuff laid over the injured part and cemented, surface to surface, by india-rubber solution, with the old material. Such patches would of course add to the weight of the envelope, and would impair the uniformity of its strength. Another disadvantage is, that in process of time it is apt, by losing some of the sulphur that was mixed, if not combined, with its substance, to become altered in quality. Whether this would ensue to any extent that would be really a drawback to its use I am not prepared to state. Finally, it is a very expensive material—the price varying of course with its thickness. It is certainly, weight for weight, by no means so strong as most woven fabrics in respect of power to resist a continued strain. Should this substance come to be used for gas-envelopes it will be advisable to make the upper parts of them, throughout their length, of stouter sheeting than the lower, to enable them to bear the weight of the parts hanging from them, without prejudicial stretching, and to give greater facilities for resisting leakage to the parts most solicited by the gas. There can be no doubt that caoutchouc, which, unlike gutta-percha, is obtained only by a tax upon, not by the sacrifice of, the trees that yield it, will become cheaper as the cultivation of the plants and the demand for their

produce increases. For very large gas-vessels, in which the proportion of the surface to the cubic contents of the figure will be very much reduced, the weight of the material will probably be more than compensated in value by its imperviousness, which must be the most important point. With small vessels for short rapid passages, lightness will be a more important object than perfect retentiveness—for these it will be likely to be rejected.

Having stated that I consider the ready flexibility of vulcanised caoutchouc a good quality in it for an envelope stuff, I may as well add that with the mode of construction of the gas-vessel which I shall recommend, the stiffness of the materials spoken of by M. Monge—pasteboard and metal—would be not only not an advantage but the reverse. The envelope must swell and gather itself together as the gas expands or contracts. It must contain nothing but the gas, and must be in contact with it over its whole surface. That the stuff, being very pliable, should be thrown into folds, is far less objectionable than that it should be liable to be strained and cracked by its inability to bend freely. With the form of gas-vessel that I believe to be essential, the folds that will result when the vessel is flaccid, will be as few and as diffused over the extent of surface as is possible. Besides, with textures that would be liable to local injury from being thrown into habitual folds, a very simple adjustment, which I shall hereafter notice, will entirely prevent any damage from ensuing to the envelope from this cause. By this means the parts subjected to convolution, by the changes in the degree of fulness or looseness of the envelope, will be freed from the tendency to wear them, and others will be brought into their place in turn.

I may here mention that thin metal plate is by no means a perfectly gas-proof material. M. Monge, indeed, seems to have discovered this for himself when too late,[1] finding that his brass sheeting was full of minute perforations. But even when there are no discoverable holes in the metal, hydrogen may be able to find its way through the pores of its substance. As an illustration of this I will adduce a circumstance which lately occurred to

[1] Monge, 'Études.'

myself. One day last October (1850) I put aside one of the small gas-holders known as Pepys's, holding nearly a cubic foot, full of hydrogen, with a small quantity of water at the bottom of the vessel. The stopcocks, all excellent ones, were turned off, and the cap of the charging aperture tightly screwed on. I left the gas-holder for three months untouched, and, bringing it out in January, I found the cylindrical reservoir which had been full of gas crushed in on three sides, as if it had been exhausted by an air-pump. The vessel was, to all practical appearance, perfectly air-tight. I had left it but shortly before this experiment full of atmospheric air, under a pressure, from within, of about six feet of water, for several hours, without the slightest appearance of leakage; and yet a considerable quantity of this subtle gas had contrived to escape without any outward pressure but that of its own diffusive tendency. Whether the diffusion-equivalent of air had passed in or not I did not ascertain; however, it seemed that but very little had entered, for the gas was of nearly the same specific gravity as it was at first. It is possible that changes of temperature may have assisted in producing this effect in some slight degree, as the gas-holder stood in a room in which a fire was lighted during the day, but in a far corner, where it could receive no direct heat from the fire. Besides, the vessel was filled during the warmest part of the day, and with gas direct from the apparatus in which it was generated; so that no loss of gas can be likely to have ensued by expansion; and the metal, which was zinc plate (japanned), was quite strong enough to have resisted the inward pressure due to the contraction of the gas on its cooling at night, and in colder weather. However, it is very likely that in some of the larger air-craft, metal plates may come to be used in the construction of gas envelopes. Zinc-iron is the material which combines most favourably all the requisites of cheapness, strength, closeness of texture, and durability in the air, and is accordingly the one to be preferred for this purpose. Its use for roofing is but an anticipation of its services in aerial architecture.

I have already spoken of linseed-oil gum, of its excellent qualities as a gas-proof varnish for woven textures, and of the probability that some experiments, carefully made by persons

versed in the art of questioning nature, would lead to improvements in its preparation and use.[1] It should be ascertained in what condition the oil-gum forms the best varnish. Either, as is the usual plan, the oil should be heated till it is in such condition that it will soon set when exposed to the air, and should be then diluted with a solvent; or it might perhaps be farther heated until it would set entirely when cold; and then being allowed to undergo this change, and become completely oxidised, the resulting solid might be dissolved and used as a varnish. I believe no material is likely to be found of more service to the aerial architect than this substance, which has already been so much used by the ballooners.

There is one point to be attended to in the use of this, as of course of other varnishes of the same nature, which is remarked by Mr. Wise,[2] namely, that a very far better effect in gas-proofing a woven texture is produced, with the same weight of varnish, by laying it on in several thin layers, than by putting it on in a single coat. The reason is obvious; the pores which must occur in every film of varnish, however thick, will be closed by the application of a second coating over the surface of the first, while the first will in like manner compensate the imperfections of the second—more or less; and so on, of course, with successive coatings. Of course the greater the number of them, the more perfect will be the imperviousness of the membrane. A close web, a thin varnish, carefully applied in several films, each well dried before the next is laid on, will of course give the best results. I should think that if for large gas-vessels it were required to render gas-proof some stout woven material such as canvas, it would be an excellent plan to saturate the cloth with the oil-gum before varnishing it. This could be done either by carefully heating it in a bath of the varnish (not, of course, by bubble-heating it in the oil, which, by the high temperature at which that process goes on, would destroy the texture), or, better still, by placing it in the cold varnish in a vessel from which the air could be exhausted. In the first case on the cooling, and in the second case on the re-admission of the atmospheric pressure,

[1] Page 99. [2] Wise, 'Syst. Aeron.,' p. 307.

the varnish would be forced into the whole substance of the tissue, with which it would come into more intimate union than could be ensured in any other way. Being withdrawn from the bath it would be now moderately pressed to squeeze out the superfluous oil, and then exposed to the air to 'dry.' The varnish would afterwards be laid on in successive coats as usual. The common oil-varnish cannot be used as a cement to unite two surfaces of cloth together. The inner part does not set, remaining quite soft and liquid. The cause of this is, of course, that the outer film of oil-gum first formed by the action of the air protects the part within from oxidation. If now, as before suggested, the oil were first solidified completely, and then dissolved, it is probable that the solution might be used as a cloth cement, for forming double textures, just as the india-rubber solution is applied. The solvent would evaporate through the cloth, and leave the oil-gum between. If a texture so formed were varnished afterwards on both sides, a most impervious texture would be produced. Of course, too, the gas-proof qualities of any of the Macintosh caoutchouc cloth might be improved by varnishing it on one or both sides with the oil-gum.

With regard to the texture which is to be the foundation for the gum-coats; silk, linen, and cotton are, of course, the materials among which the choice would lie. Hemp, perhaps, for large vessels might find its use. Silk is probably at present of a higher price than would bring it into general use for gas-vessels. Of course if the silk-producing powers of this earth of ours were developed to a tithe of its capabilities, all the working hydrogen, as well as all the working men and women in the world, might be clothed in the fleeces of the mulberry. There is no doubt but we might grow silk enough in England, if not for the dress of our whole population, at least to clothe the gas for all Her Majesty's air-craft mails; whether more cheaply than we could get it from impoverished India, experiment will one day ascertain. Probably not. At any rate, we probably could not grow here the caterpillar-fibre from which the Tussore silk is woven in India. I have already mentioned this texture as being recommended by Mr. Wise, and have remarked[1] that the web is not

[1] Page 101.

sufficiently close to make it a good envelope stuff. The valuable quality of this material is its toughness and strength. Of course, nothing is necessary but to provide the natives with good looms and with instruction, to enable them to weave for us from the same cocoons a texture as close as can be made from any other silk.

But we can beyond a doubt obtain from our own soil a material which will furnish each of the requisites of gas-envelopes almost as perfectly as can any other source. The destiny of flax is not yet half developed. If it has already earned the title of 'usitatissimum,' the praise is fully as prophetic as historical. It is not for our clothes, probably, that our farmers will have to grow flax, but for aerial gas-vessels. Linen is unquestionably as far inferior to cotton as a material for clothing, in which warmth and softness is requisite, as it is superior to it for all purposes in which strength and durability are essential qualities. Cotton is so far below flax-fibre in point of tenacity and firmness, that where linen is to be had, the former will undoubtedly be rejected as an envelope stuff. America may, perhaps, build her gas-vessels of Carolina tree-wool; England will, no doubt, trust to her flax-thread.

That this precious plant is to be extensively grown in England some day is very generally believed, though for what purpose is not usually very obvious. That cotton is the true material for human clothing, whether for comfort or for elegance, anyone will maintain who has worn shirts of the two materials, or has compared the old muslins of now-extinguished Dacca, with the finest textures of Cambray. Aerial navigation will, however, find uses for the flax, and application for the ingenious inventions of M. Claussen. The construction of gas-vessels is clearly the purpose for which the 'Linum' was sent upon the earth. It will be to the air-sailor almost what the fan-palm is to the Guaranis of the Orinoco. It will supply them not only with the best fibre for giving strength with sufficient lightness to their envelope, but with the best of materials for making it impervious to the gas; for it is from the seed of this very plant that the oil is obtained of whose valuable gum-forming qualities I have already spoken. And if the same seed, after having yielded up its oil, does not

supply the aeronaut at once with food, without the intervention of the clumsy and wasteful process of converting it into beef, it will be the fault of the man, not of the nutritious grain. It must not be forgotten that hemp too is gifted with at least the two-fold virtue of yielding web-fibre and gum-oil. So far of the material of the envelope.

Now of the construction. Without here speaking of the form of the gas-vessel, I may premise that, in most cases, the envelope will be built of gores or segments of the material running from end to end of the figure. Its most usual arrangement will, I believe, be as a loose pliable bag enclosed within an outer inflexible case. This will be the ordinary condition when the material is vulcanised caoutchouc, or a woven texture made airproof with an elastic gum. When a metal, or any other rigid substance, is used in its construction, there will be no need of an inner bag. The metal plates of which the gas-vessel is built will supply the firmness and retentiveness of shield and envelope. Since, however, the gas must be allowed to expand and contract, without throwing any strain on the metal, the vessel must be furnished with an inner membrane, equal in size and shape to the lower half of the entire envelope, and attached by its edge airtight to the interior of the vessel, all round the line of its equator. The gas would be contained between this diaphragm and the upper half of the metallic vessel, of which the lower half would only serve the purposes of meeting the resistance of the air to the moving body, and of maintaining the stiffness and strength of the system. As the gas swells or shrinks with changes of pressure or of temperature, it will drive out or draw in, through an aperture left in the metal for the purpose, air that may lie between the bottom of the vessel and the membrane that retains the gas.

I shall hereafter have occasion to show that it will be necessary, or at least very useful for some kinds of air-craft, to be provided with two envelopes, one below the other, within the same gas-vessel; or with a single envelope divided into two compartments by a horizontal diaphragm.[1] But as this is a special provision for another of our conditions, I shall say no more about it in this place.

[1] See Chap. XI. below.

I have said often enough, that gas is not to be discharged from the gas-vessel except upon extreme emergencies. So necessary does this seem to me, that I do not believe that any valve ought to be admitted in the structure of the gas-vessel for the purpose of allowing its contents to escape—except such as may give vent to excess of gas when the envelope is charged to repletion and requires relief. For this latter function at least one safety-valve must be provided: two will be better, in case one should become fixed in its seat, and so should endanger the bursting of the receptacle. Such safety—or rather tension—valves must of course be placed at the bottom of the envelope, so as not to be exposed to pressure until it is fully inflated. They will, of course, open outwards, and will be kept closed by springs, the power of which is considerably less than the force which, exerted on an area equal to that of the valve, would strain in the least degree the texture of the envelope. I hold it, as I have before stated,[1] to be of great importance that the envelope should not be exposed to the 'pression intérieure' even 'légère' on which M. Monge relies so much. There is no substance except vulcanised caoutchouc and metals, to whose tenacity we ought to trust in this position, and not too much to theirs. The slightest stretching will impair for the time, and probably for a permanence, the imperviousness of our gas-proof textures. We must treat our envelopes, as well as their contents, lovingly. Generally they should be constructed with a portion of their bottom part considerably weaker than the rest of their membrane, so that in case of the craft rising accidentally to too great a height in the air, and of the safety-valves being insufficient to relieve the envelope of the pressure of the gas, it may burst at the bottom and not at the top. If the latter result ensues, a catastrophe must follow unless the outer shell be sufficiently gas-tight to retain the hydrogen. If the bottom be rent, only the excess of gas can escape, the upper part of the envelope retaining the rest, and all will be safe.

The valves of balloons, I believe, are generally made to depend for their tightness on the close fitting of two surfaces of wood or metal, kept covered with grease. The unctuous qualities

[1] Page 63.

of oily matters are diminished by cold: in the upper regions of the air this may take place to such an extent as to solidify the substance and to cause the anointed surfaces to adhere together. Such a result might endanger, if not the lives of the voyagers, at least the integrity of the gas-vessel. This is not the case with the balloon from whose gaping mouth below the gas is allowed to escape freely, and often, no doubt, to get well mixed with air before it escapes.

A valve free from this inconvenience, and fully as air-tight as, if not more so than, one of the usual construction may be made thus. Let the aperture in the envelope be of any shape—for instance, as usual, circular—and let its lip be strengthened with a flat ring of wood or metal. Let the lip be faced with a ring of vulcanized india-rubber sheet. The valve, of course, will be a circular disc, or two semicircular plates closing upon and lapping over the edges of the aperture. Let the whole circumference of the valve be armed with a hard blunt metallic edge (or with more than one) running round the plate, to which it is firmly attached at its back, and projecting towards the valve seat at right angles to the plane of the disc, after the manner of a crown-wheel before the teeth are cut, or of a biscuit punch. This edge, when the valve is in its place, will be pressed into the caoutchouc ring-bed, and will form a most perfect trap for the gas, not liable to leak, nor to stick fast in its seat. The adjustment of the spring and of the hinge, or pin and socket of the valve plate, need not be spoken of; it admits of great variety. It is merely to the adaptation of this method of closing the aperture that I wish to call attention.

A simpler method, and one which will be applicable in some cases, is that of carrying a pipe from the gas receptacle to a vessel of water, in which it dips below the surface. This method, which I find proposed by Sir G. Cayley,[1] has these other advantages,

[1] 'Mech. Mag.' vol. xxvi. p. 419. This gentleman suggests that it might be useful to allow the gas to escape through the safety-valve into a secondary gas-vessel, from which it might be returned to the proper envelope, when pressure in the latter should diminish. Unless it were necessary to keep up tension from within upon the envelope this would be superfluous. Such an appendage is, therefore, useless in the system which I am describing.

besides that of simplicity, that it involves no mechanical fittings that are likely to get out of order, and that the amount of pressure may be adjusted in a moment by dipping the tube-mouth more or less far into the liquid. It must be remembered, however, that to resist pressure is not the function of this valve (as it is in the scheme of Sir G. Cayley), but to allow the escape of superfluous gas, and to cut off the outer air from all access to the interior of the gas-vessel.

An appendage to the safety-valves, which will probably be found useful by the master of the air-craft, will be a gas-meter. If the safety-valve opens into a tube which discharges through a meter, all the gas that is lost by expansion will be registered, and the engineer will know how much fresh gas must be thrown in to restore the due buoyancy of the craft, and the pilot will be warned to be careful not to diminish the buoyancy by any needless ascent.

The valve of balloons is, as is well known, finished in a cubit above, like that of Noah's Ark, which, as a good gas-vessel, was pitched within and without with pitch. Such an upper valve is of course constantly urged from within, by the full upward pressure of the whole column of gas below it, of which the section is the area of the aperture, and the length is the depth of the gas in the vessel. It must, therefore, open inwards, that this pressure may tend to keep it closed instead of to open it I shall not advocate the use of any such apparatus in a navigable gas-vessel, believing that it would never have to be resorted to, except in cases of rare emergency, which other appliances, involving less danger and inconvenience, will meet with equal readiness. The following are the chief objections to the top valve: Firstly, it offers, through any possible imperfection in its structure, an outlet at which the precious gas will be continually escaping; it would be, in fact, a weak point in the constitution through which, from the first day of its use to the last, the life of the craft would be liable to impairment: Secondly, it would be possible by mistake in service,

If the gas is to be kept, the gas-vessel proper must be made large enough to admit of its expansion, and to contain it all, which, of course, it will do with a less amount of surface, and therefore of weight, than can be contrived by any other arrangement.

or by accident, to be thrown open, when not desired. This would not only injure the buoyancy of the system, but if the derangement continued, would endanger the safety of the craft and the lives of all its passengers: Thirdly, it would not be resorted to of necessity more than once, perhaps, in a dozen years; and when the hour of need came it might, from disuse, be found in disorder: Fourthly, it can never be ascertained by trial to be in working order without a sacrifice of the gas, which we most earnestly desire to preserve. To these I shall add, though it will not be an objection of any weight with others than myself, that there would be some inconveniences in fitting a top valve to such a vessel as I shall propose for general, or at least for commencing, use. This inconvenience would arise from the necessity that its use would entail of fastening the top of the envelope at the part where the valve might be inserted, to the outer case of the gas-vessel, in which I desire that the envelope should be nearly free. There is no difficulty in contriving several modes in which this might be managed, but I shall not needlessly occupy space by describing them.

I therefore would have no top valve in my gas-vessel, as being an encumbrance, which would render the fulfilment of our first condition—that the envelope shall be gas-proof—more difficult than it is already. I need scarcely add that there can be no needless leakage of gas at the bottom valves which I propose, because the gas would never be pressing against them, till the envelope is quite full, and requires relief.

I shall reserve for a future chapter [1] the means by which, in case of necessity for sudden diminution of buoyancy, I would discharge gas from within the vessel, when the envelope might not be full. It would be out of place here to treat further of this, which pertains to another of our conditions. The end for which I have had to provide in this chapter is that of enabling the envelope to retain its gas, not to discharge it.

[1] See Chap. XII.

CHAPTER IV.

CONDITION 2.—THE VESSELS MUST BE OF ELONGATED FORM, THAT OF LEAST RESISTANCE.

THIS, another of our cardinal requisites, is, as I have shown already, one of those on which numerous and careful experiments are required—experiments which, if they are left to any individual to work out by himself, will win for him who draws through them the truth, if he desires fame, laurels that will long be green. The enquiry too which is wanted on this head is one which not only can go on collaterally with others that must be made in the service of our art, but which need not be completed before trials of the second sort, of those I mentioned at the beginning of the last chapter, are commenced. The first air craft that is constructed need not be built of the most perfect form; if it were, indeed, it would falsify the law of gradual development, which prevails in all nature, cosmical as well as artificial.[1]

If our first gas-vessel is put together of a reasonable good shape, of one that will work, we may be 'contented' as Sir G. Cayley says,[2] 'to leave the rest to future improvement.' We shall not want to achieve the highest possible velocity in our first attempts. What we have to do, then, is to commence our experi-

[1] The distinction which is usually drawn between nature and art, and which is such a favourite for an antithesis, is altogether unnatural and unartistical. It implies that it is not according to nature that man should subdue the earth; and that man in building steamships and aircraft is not as much doing his appointed work as are the plants in budding and the birds in building their nests. The human-artificial is but a particular case of the natural.

[2] 'Mech. Mag.' vol. xxvi. p. 420.

ments in navigation with some fair figure, taking what hints we can get towards cheating the air of its resistance.

Before, then, putting down what notions I have to give as to 'experiments in consort touching' the resistance of the air, I will suggest an 'experiment solitary touching' a shape that may be useful in the building of a gas-vessel. The fastest fishes and birds are framed upon a model of which the general idea is clearly a spindle form tapering off more suddenly towards the head than towards the tail; the greatest thickness being placed nearer to the fore than to the after hand. And the same type prevails in the forms of the fleetest quadrupeds—greyhounds, racers, hares. It would be interesting, as an illustration, to enquire by a general examination of the quick-moving fishes and birds, what are their proportions as respects length and thickness, and the position of the greatest cross section. Precise instructions, however, as to the forms best for our purpose, cannot be obtained but by careful experiment; organic nature only gives us hints. Among fishes, mackerel, salmon, and sharks,[1] and, among birds, the swallows and true falcons are suggestive. Now with these animals the greatest thickness is about one third or at most two fifths of the length from the fore end. From the extremities of the lesser axis the outline slopes off with a gentle curve towards each extremity. In most fishes the depth at any point of the length is greater than the horizontal breadth at the same part. This is also slightly the case in birds. The object attained by this increase of depth in birds is evidently the attachment of the pectoral muscles, which require the downward extension of the keel of the breast-bone. In fishes, there is no doubt that the end served is

[1] The sharks and dog-fishes have a peculiarity which admirably fits them for dashing through the liquid they inhabit; their nose forms a perfect cutwater, the mouth being on the lower side of the conical bows, and at some distance from the point; and, by the way, as a point in steering, one limb of their tail is always considerably more developed than the other. This enables them to twist their body rapidly round its long axis, so as to bring their hungry mouth into any position, up, down, or sideways. It is worthy of remark, too, that if they carried a swimming-bladder, which most other fish do to keep them floating back uppermost, they could not execute this manœuvre, which is likewise facilitated by their bodies being circular in cross-section instead of oval, as are those of most of the rapid fishes.

the maintenance of their body in stable equilibrium with the belly downwards. There is no reason for believing that the sideward flattening of the form of these animals has any effect in favouring their speed; except so far as the fish's tail is concerned, which will, of course, strike the water more effectively the flatter it is in the direction of the blow. This, however, is secured by the plane surface of the tail itself; the tailward end of the body is less flattened than the rest of it, the propelling muscles giving fulness to the lateral outline. Experiment alone can determine whether any such modification of the form is more favourable to speed through the air than the figure of a solid of revolution of equal sectional areas. It is of course possible that it may be. There will be a certain practical advantage in the construction of air-craft, conferred by adopting the flattened form; to this I shall hereafter allude in considering the suspension of the other part of the craft from the gas-vessel. But it entails a corresponding disadvantage—namely, that the weight of the gas-vessel, the contents being the same, is greater with an oval, than with a circular section. Again, the construction of a figure of revolution is a much simpler and easier process than that of a compressed form. I shall therefore recommend the adoption, for the first air-craft, of a figure of revolution; of one in which the greatest thickness is at one third of the length from the fore end.[1]

I am far from believing that the form which I propose is the best that can be obtained. Indeed, I am quite sure that it is not; for I believe that the larger the vessel is, the thickness remaining the same, the less will be the resistance to its progress. The figure of M. Jullien's as represented in 'L'Illustration'[2] is certainly a better one, being slenderer. With this exception I believe that the one suggested below is the best form that has yet

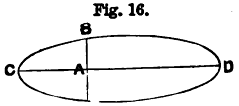
[1] It is understood that Mr. Scott Russell's experiments indicate that the best form for ships is one in which the greatest breadth is nearer to the stern than to the head of the vessel ('Mech. Mag.' vol. liv. p. 268). If, however, it be true that this kind of form is the best for ships—whether for steamers or for sailers—it must be remembered that the conditions of a vessel moving on the surface of a liquid in which it is partly sunk, are altogether different from those of one propelled through a single fluid in which it is entirely immersed.

[2] See page 87.

been proposed for the vessels of an air-craft. I select this shape in preference to one of greater length, as being one of which the proportions are pleasing to the eye, and which presents a degree of elongation, and a 'fine run' sufficiently decided to diminish the resistance of the air to a very considerable extent. Again, the attenuation is not great enough so to alarm the minds of the sceptical, by the amount of apparent difficulty in the ensurance of stiffness, as to be likely to deter them from entertaining my suggestions as being worthy of trial. But this latter consideration belongs to our third condition, to be discussed in the next chapter.

The provisional form, then, of which I recommend the gas-envelope of an air-craft to be made for trial, while experiments are going on for the purpose of ascertaining the best shapes, is that of which fig. 16 represents the section taken through its longer axis. It is circular in all sections in planes at right angles

Fig. 16.



to this. It is formed by the revolution of two half-ellipses having the same semi-minor axis, A B: and of which one has its semi-major axis, A C, equal to twice A B, while that (A D), of the other is equal to four times that quantity. The two semi-prolate spheroids thus formed are placed together, base to base, and form a figure of which the proportions, as respects length and breadth, were those observed by Noah in the building of his ark.

It must be observed that it is for the flexible envelope that I specially recommend this form. The outer case of the gas-vessel, which is to contain the envelope, and of which I shall speak in the next chapter, should also be made of this form, at least as respects its framework. The actual shape of the gas-vessel may be modified at pleasure, after the whole apparatus is finished, by adding caps of various forms to its beak and tail: it is probable that small variations in these points would make considerable difference in the amount of resistance suffered by the vessel from the air. Whatever form is the best for the gas-vessel is of course the best for the other vessels, one or more, that may be suspended

to it: at least we must assume that such is the case until it is shown by experiment that, as respects the relation of the resistance of the air to forms, there is one law for the great and another for the small; which is possible. I should propose therefore that the boat which carries the propelling power should be of this same form, with such modifications as to cut-air and stern as it may be found desirable to give to it, further to facilitate the cleaving of the air. For of course the resistance of the atmosphere to every part of the system must be considered, and diminished to the utmost degree.

Whatever may be the proportions of length to breadth as respects the vessels of the air-craft, I believe it will be found, that the forms best suited to their functions of rapid motion, will not differ very much from figures composed of parts of prolate spheroids. At any rate the forms will be found to be such that some figure of this kind will fit into them pretty closely as a core or rather as a lining. It is for this reason that I would avail myself of the figures generated by the revolution of ellipses round their longer axes for the shapes of the inflated envelopes.[1] These figures have the advantage of being readily constructed of gores or segments, cut according to a pattern; and of enabling us to calculate at once from a formula what are their cubic contents and the area of their surface, the latter being necessary to be known in estimating their weight.

In the Appendix[2] will be found a table of measurements by which gores may be cut, for the construction of shells or envelopes of any size of this particular figure—the provisional vessel-form, of the proportions above stated, and which I shall represent as the double-semi-prolate spheroid, 2 | 4.[3]

[1] The reader who is not versed in geometrical language may be glad to be informed that a solid supposed to proceed in this way from an ellipse is called a prolate spheroid, as distinguished from an oblate spheroid, which is formed by spinning an ellipse round its shorter axis. The earth is of the latter genus. These figures are sometimes wrongly called ellipsoids, which are things that are elliptical in every section. Spheroids are, of course, circular in all sections made at right angles to the axis on which they are spun.

[2] Appendix D.

[3] See page 219.

There is, likewise, in the Appendix[1] a table, calculated with care, which shows the dimensions and contents of gas-vessels of this form, for various sizes corresponding to a scale of lifting powers.

I have thought it right to give these tables, with the view of saving labour to any associated experimenters or individual speculators who might wish to try or to imagine the results of such an arrangement as I shall propose.

I now proceed to state what further I consider necessary to be done by some person or society before we can set to work in earnest to navigate the air.

There are two primary elements in our problem, by determining which its solution would be at once made plain. The question is simply this—What is the amount of resistance to be overcome? What forces have we at command for opposing this resistance? It is very curious that no one seems to have thought of attacking it by going at once to the bottom of the matter. The books are full of hypothetical cases, showing that it is most likely both that we can and that we cannot vanquish the resistance: the sanguine and the slow of belief both equally seem to prove their points. But there are actually no facts to be adduced on either side, from which any precise numerical result can be affirmed one way or the other. If I did not know that there are facts sufficient to prove generally that we can succeed, I should not write these pages. But this is not enough: what is wanted is a knowledge of the actual amount of resistance to be overcome, as well as of the force that we can oppose to it. If, instead of torturing their brains for mechanical combinations of which they could not state the duty, inventors had set to work to ascertain these points, or to entreat those who had the means to ascertain them, we should have been navigating the air by this time. One of the chief objects of this book is to point out what is to be done towards answering the two clauses of this enquiry. The second of these clauses—the power question—relates to the last of our twelve conditions, and will be treated in its turn in a future chapter; the first belongs to the head which we are now considering.

[1] Appendix E.

We want then a series of careful experiments on the resistance of the air; the results of these should inform us what is the solid figure that, when moving through the air at given velocities, suffers the least resistance to its progress, and, therefore, requires the least force to produce its motion. It is most likely that different forms are the most favourable for different velocities; so that the shape which required the least force to move it through the air at 10 miles an hour, would not be that which would require least force to move it at 100. All this must be determined; and data must be obtained from which the amount of force necessary to propel a given figure at any required speed may be at once correctly calculated.

Now it is utterly impossible that all forms can be tried. The most that can be done is, acting on such hints as we can get from nature or from mathematical theory, to try the most promising forms, and so to arrange the results as that they may all be at once comparable with each other.

The suggestions which I wish to offer as to the course of experiments are of two kinds: the first relates to the forms to be experimented with, and the order in which they should be submitted to trial; the second to the mode in which they are subjected to the test.

Now, as I have before stated,[1] whatever may be the best form, it is certain that a figure composed of parts of prolate spheroids may be found which shall differ from it so slightly that a trifling addition to one or both of the extremities will bring it, practically, to the true shape. I would recommend that prolate spheroids should form the chief subjects of our experiments. First of all a unit-measure should be selected, which must be the length of the minor axis of all our spheroids. A circular plane having this line as its diameter must be taken as the standard of comparison. A careful series of experiments should be made with this circular plane for the purpose of determining the resistance to its motion at various velocities from that of 1 to 100 hour-miles.[2] As the table should be very complete,

[1] See p. 214.

[2] By an 'hour-mile' I mean a mile moved through in an hour. Thus also a speed of twenty 'second-feet' would mean one of twenty feet in a second of time.

it would be well to ascertain the resistance for all the velocities represented as miles per hour, by the whole series of natural

Among all the remnant rags of barbarism which hang about the trappings of our civilisation, there are few more annoying to those whose attention is ever called to it than is the difference of the various weights and measures which are used among the several nations who are doing, among them, the work of the world. Men of commerce and men of science must be equally fretted by this vexatious clog upon their movements. It is perhaps a more serious inconvenience than that of the differences of coinage. We shall do without money some day, but we shall always want weights and measures. When these latter are reduced each to a common notation, the alteration of the money-form would naturally and easily ensue as a step to the use of the labour-exchange notes, which will hereafter regulate the transactions of the industrial world; and to the common adoption of a universal language for our entire race.

The amount of time lost, and consequently of retardation of progress among scientific men, by the necessity of multiplying and dividing the numbers they find in books before they can twist them into such a shape that either they or their neighbours can understand them, might form an interesting exercise for a calculator. A collection of tables of all the various systems, set up apparently for the very purpose of keeping men asunder by making the most of the confusion of tongues, would be interesting hereafter as a monument of elaborate discord, and by bringing the inconvenience forcibly before men's minds at present, would stimulate them to aid in its removal. What would be easier than the formation of a society in which there should be representatives of all nations, and which should have for its objects the settlement of a table of weights and measures acceptable by all the world, and the endeavour to get it introduced into use in all their several countries? There would be two points for consideration in their problem:—First, that the standard must be one derived from some natural function or attribute of the world, to which it could be referred for correction in future times; second, that it must be one differing as little as possible from those in use amongst the most industrious peoples. To these may be added that the length unit should, if possible, be that on which the proportions of the typical human body are founded.

This would be essentially a social movement. Each nation must be prepared to make some temporary sacrifices of convenience or of peculiar vanity for the common good. If any people should resolutely stand out against the choice of the others, for their own old standard, the brotherhood would simply have to be formed without them. Of course, it would not be necessary at first and at once to substitute the new scales for the former ones. The old quantities might continue to be used among each people for their own internal purposes; while in all transactions or communications

numbers from 1 to 100. The results of the experiments on this disc should be placed as the first column in the table, as the standard of comparison for the following columns. The horizontal lines would receive the numbers in each column corresponding to each velocity in order.

The rest of the columns, then, would be filled by the results of the experiments made with the spheroids. The first of the spheroid family that would be examined would naturally—rather for the sake of making the results into a perfect whole for the deduction of a law, than for any practical utility as respects our art—be one in which the major axis is equal to the minor axis, that is, a sphere.

Now as I have already indicated, the figures to be tried are not all to be exact spheroids; many of them, of which my provisional shape is an instance, must consist of two different half-spheroids placed together base to base. For sake of simplicity I would suggest that the semi-major axes of all the half-spheroids should be integral multiples of the semi-minor axis which is to be common to all. And I will represent each figure by a formula of two numbers, which represent respectively the ratio of the major axis of the two halves to the common minor axis, which is considered as 1.[1] Thus 2 | 4 represents the provisional figure, and the sphere would be denoted by 1 | 1. This notation which I shall adopt will simplify very much the nomenclature of the forms and reference to the results, and will enable me in a few words to state what I think necessary to be done. I need only add that the left-hand number is intended to represent the head end, and the right-hand the tail end of the figure.

with foreigners they would interpret their particular expression into the numbers of the general scale. In process of time the new arrangement would become habitual, and would exclude the ancient weights and measures from use altogether.

Let us hope, too, that the experiments of the Aeronautic Society will be the first of which the results will be tabulated in the 'hour-miles' of the universal scale. We have all agreed about the hours already, we have only to harmonise our miles, that he who runs might read.

[1] Therefore the symbol of each compound spheroid is not merely a ratio, so that it must be borne in mind that 2 | 4 represents a very different figure from that indicated by 4 | 8.

Experiments, then, should be made with the following spheroidal shapes:

1 | 1 . 1 | 2 . 1 | 3 . 1 | 4 . 1 | 5 . . . .
2 | 1 . 2 | 2 . 2 | 3 . 2 | 4 . 2 | 5 . . . .
3 | 1 . 3 | 2 . 3 | 3 . 3 | 4 . 3 | 5 . . . .
. . . .
. . . 5 | 5 . 5 | 6 . 5 | 7 . 5 | 8 . 5 | 9 . . . .
. . . 6 | 5 . 6 | 6 . . . .

and with a long series of others formed on the same law.

I shall not put any limit to the number of forms to be tried. The numbers will of course be increased in both directions until it is found that any further extension of length tends to increase instead of to diminish the resistance. Should any addition to the length beyond a certain point be found not to have any effect in altering the resistance, either by lessening or by enhancing it, the experiments must still be continued in the same direction until, if this should be found to occur at all, the resistance begins to increase rapidly with the length. For every addition that can be made to the length without increasing the resistance is so much sheer gain. If it tends to diminish the resistance, which there is no doubt all the earlier increments will do very considerably, it is a gratuitous benefit of such exceeding value that words can scarcely express the delight we ought to feel in the result. The benefit obtained in our art by the increase of length of the gas-vessel must be so enormous that at first sight one almost feels inclined to doubt the correctness of one's inferences, and, if not to hesitate in accepting such a boon from the hard laws of the physical world, to doubt whether we can take it without paying heavily for it in some other way. Nothing indeed, but the marvellous exuberance of nature, the lavish prodigality of means which we find in every hole and corner of God's world when fairly and faithfully examined, will enable us to reconcile the advantages here obtainable with what is possible, or even with what it is fair for us, for whose sake the ground is

cursed, so that we shall eat of it in sorrow all the days of our life, to accept from matter, or from the Giver of it.

But to be more explicit. Every advocate of aerial navigation has triumphantly pointed to the undeniable fact,—that the contents of regular geometrical solids vary as the cube, while their surfaces vary only as the square, of the diameters—as a proof that their hobby is a practicable one. For since as the diameter of the gas-vessel is enlarged, its lifting power, which is measured by its contents, increases much more rapidly than its weight, and than the resistance which the air opposes to it, both of which depend upon its surface, whatever be the amount of resistance to be overcome, there must be a certain magnitude of gas-vessel which will have buoyancy enough to lift the mechanical power necessary to neutralize the opposition. This is an instance of one of those immense advantages which are stored in nature for those who know how to seek them rightly. Hence, it is rightly argued, justice can never be done to the art by experiments on a small scale; and, it is generally added by the most careful reasoners, none but air-craft of a most enormous magnitude can ever have a chance of success. This latter point I doubt, partly because I believe that sources of power far lighter than those contemplated by the advocates of the colossal air-ship are at our command (but of this hereafter), and partly because of the other enormous gain of which I have spoken, and by which, as it seems to me, air-schemers have neglected or despaired to profit.

We received a hint of this latter point a long time ago, when Col. Beaufoy first observed the fact, at first considered paradoxical, that the resistance to a sphere drawn through the water was considerably diminished by cutting it in half at right angles to the line of its motion, and inserting a cylinder between the bases of the hemispheres. The reason of this is, however, very simple; the resistance is due partly to increased pressure upon the front surface of the sphere, partly to diminished pressure upon the after surface, where there is a tendency to the formation of a vacuum, by the body moving forward before the fluid can flow into its place; or, in other words, where it is running away from the pressure due to it from behind. Now in the case

referred to, the first cause of resistance is not affected in any way by the insertion of the cylinder, and the second is diminished by the lengthening of the hinder part which fills up the void, and so receives the due pressure from the liquid behind it, and transmits it to the rest of the body. Now this fact is but of trifling importance to the art, for the benefit of which Col. Beaufoy's experiments were made, at least in its present state; for there is supposed to be a practical limit to the lengthening of ships. Besides, it was known already that the after part of a ship was at least as influential in determining its rate of sailing as the fore part, and it was supposed that 'mackarel-tail' or a 'fine run' is requisite to its speed; and the most, perhaps, was already made of it. But in aerial navigation—and there is every reason to believe that the influence of length is the same with bodies moving in air as in water—this principle is, as I have said, of the very highest importance.

In air-craft the advantage derived from increasing the length of the gas-vessel is twofold. Not only will the resistance of the air to the gas-vessel be diminished by increasing its length, while its greatest thickness remains the same, but its power of overcoming that diminished resistance will be exalted by lengthening it. For every addition to its length is, in fact, an addition to its cubic contents, and therefore to its means of lifting machinery, the source of power. Again, if, the contents remaining the same, the length is increased, the resistance of the air will be doubly diminished on the one hand by the elongation, on the other by the contraction in thickness. To this may be added that by reducing the thickness of the figure, the weight hanging from the upper part of the envelope, and therefore the strain on its textures and liability to leak, is lessened.

Now it is possible that there is some limit to the diminution of resistance by increase of length; but even when this advantage is no longer obtained, the full effect of the other—the gain in lifting power—is still available, and this without any loss or drawback except that which is due to the weight of the added length of the gas-vessel. It is likely that when the length becomes very great, the air makes its effect felt by another kind of opposition, distinct from its resistance in front: by its friction on the

sides of the moving body. But this can only be the case either when the fore quarters of the figure are drawn out, or when the middle is prolonged, as a cylinder, or other figure with parallel sides. When the elongation is confined to the part aft the greatest thickness, and when the whole of this part is tapering, as is the case in all spheroids, the walls of the lengthened stern are ever running away from the air, not directly through it, and therefore cannot suffer much friction from the fluid. Again, that in water practice the limit of diminution of resistance is not very soon arrived at, is shown by the fact that our eight-oared river racing-boats have been of late years gradually increased in length, with increasing advantage to their speed, till at Cambridge, which is the Alma Mater of rowing, a stop has been put to progress in this direction, not by the difficulty in building or in propelling, but by the width of the river, which will not permit a boat much longer than sixty feet to turn with any safety. But in river-boats, the same kind of effect has been further extended by narrowing the boats in the beam, so that the dimensions at the gunwale of the best eight-oared 'outrigger' racing-boats, as built by Messrs. Searle of Lambeth, at the present day, are:—extreme length 64 feet, extreme width, at the middle of the length, 2 feet 3 inches; and those of the single sculler's boats are 30 feet, by 1 foot 4 inches: giving respectively the ratios of minor to major axis, as 1 : 28·5, and 1 : 22·5 respectively. The proportions of the bottom of the boats, where immersed in the water, are of course finer still, for the breadth diminishes more rapidly than the length from the gunwale downwards. The Chinese, however, seem to have been a-head of us in this respect for a long time, as they are still perhaps in some other matters. Dr. Arnott, who, we may presume, speaks of what he has himself seen, says, 'There are boats used in China, called *snake boats*, which are only a foot or two broad, but perhaps a hundred feet in length, and when moved, as they often are, by nearly a hundred rowers, their swiftness is extreme.'[1]

[1] 'Elements of Physics,' 5th ed. 1833, vol. i. p. 474. It may be worth while to remark that if the boats are only a foot or two broad, the rowers must sit in single column, and that they can scarcely do their work with

These facts in aquatics are, however, only illustrations. Returning now to the air, we find a few hints that are closer to the

less than three feet of length to each man, so that if there are seventy rowers the boats must be at least two hundred feet long. I mention this because I wish to show that very great length is not only not impossible in a floating structure, but practicable and advantageous.

It seems somewhat curious in the present age, when such great efforts have been made to increase the speed of locomotion on land, and to some extent upon the inland waters, that we should still be content with the very slow pace at which our sea-steamers crawl across the ocean. The rate of the river steamboats has been somewhat increased by lengthening them out, not so much in this country as on the rivers of North America. But the builders of the ocean-ships still seem to be adhering scrupulously to the original instructions of Noah, as to the proportions of breadth to length. The dimensions of Noah's ark with respect to these directions were: breadth, 50 cubits; length, 300 cubits (Genesis vi. 14). Those of the steamer 'Great Britain:' beam, 51 feet; extreme length, 320 feet ('Mech. Mag.' vol. xxxvii. p. 245). Those of the 'Baltic,' the longest of the 'Collins' line of Transatlantic steamers: beam, 45; length on deck, 287 feet ('Mech. Mag.' vol. liv. p. 324). The ratios, then, of breadth to length in these three vessels are respectively: 1 : 6, 1 : 6·29, 1 : 6·37, nearly the same, showing a great reverence on the part of British and American ship-builders for ancient practical science. It is to be remembered, however, that though Noah's ark is the true type of floating craft in the experimental stage, extreme speed was not the object sought in the construction of the primeval ship. Now no great velocity ever can be obtained either upon or through the water, without building the vessels of the form best adapted to speed, that is, of great length. River boat-builders have shown that the speed of their craft is greatly enhanced by increasing their length. Clearly, then, if we want to shorten the time occupied in crossing the Atlantic, we must lengthen out our steamers, to increase the capacity for receiving speed from a given amount of power.

But when the 'Great Britain' was built, everybody was alarmed for her safety, because she was too long, and would break her back across some great ocean wave. Now this danger awaiting the 'Great Britain' arose not from her being too long, but from her being too short. If we were to take our river racing boats as the models of our swift ocean steamers, we should not only enable them to attain the speed which we desire, but we should free them from the danger of either breaking their backs, or of pitching head foremost beneath the surface. If vessels were built having the same ratios of breadth to length as those of our river racing boats (1 : 28·5), and bearing the same proportion in size to the ocean waves that these latter bear to the ripple-ridges on the Thames, our steamships would be perfectly safe.

point, and still bearing evidence in favour of the expediency of giving great length to bodies moving through the air. I have

Nobody ever heard of an eight-oared cutter breaking her back across a wave on the river. And the reason is simply that they are so long that they are always resting on the water at a sufficient number of points to give them secure support. Of course when they are not floating they run greater risk of injury, but care in handling and sustaining them is all that is necessary for their preservation when in the dry dock. Such vessels for ocean transit must of course be enormously large—so let them be. Suppose the height of the river waves, with which our swift-rowing boats are liable to meet, to be about ·75 feet in vertical height from crest to trough-bottom, the extreme length of the boats being 64 feet. The highest waves known to occur on the ocean are 40 feet high, as measured in this manner. (See Dr. Arnott's 'Elements of Physics,' vol. i. p. 461; and Mrs. Somerville's 'Physical Geography,' vol. i. p. 327.) The length, then, of such a ship as I am conceiving would be about $\frac{64 \times 40}{\cdot 75} = 3413{\cdot}3$ feet, say 1140 yards; two-thirds of a mile nearly, with a breadth of beam (at the ratio of 28·5 : 1) of 40 yards. Surely a people who can build the Menai bridges, and can run up the Crystal Palace in a month or two, need not laugh at such a notion. With the methods which we now possess of dealing with iron-plate, and making it into rigid structures, there would be no difficulty in building such ships. The question of the strength of the materials would not come in with its threats to put a limit to our designs; for the body being always floating would not have to support the strain of its own weight, which would be disposed in the manner most favourable for its security. Of course such a ship would require no masts, it would be a mere hull—a floating house roofed in, and fitted with propellers. The vast additional floating power, got by the increase of length, will enable the ship to carry a far greater amount of engine power and fuel than any of our present vessels can bear; and this not only without sinking the vessel deeper in the water than, or so deep as, our present steamers lie, but the resistance which the power has to overcome, supposing them to draw the same amount of water, will be far less than that which opposes our old-fashioned ocean craft. With such vessels as these the world might be circumnavigated half a dozen times without any stoppage to take in fuel. When the daily sea surface traffic to America, and the weekly service to Australia and New Zealand is established, it must be by means of such ships as these, which, while the passengers are darting through the air, will rush across the ocean with their merchandise at a scarcely lower rate of speed. For facilitating repairs, the vessels would probably be built in separate water-tight segments, bolted together when ready for sea like the dorsal vertebræ of a bird's trunk. One of these, on occasion of injury by wear or tear, could be detached from

already mentioned arrows as the best models for gas-vessels. The best arrows for men, as made by Mr. Buchanan of 191 Piccadilly, are 28 inches in length, and $\frac{3}{8}$ths of an inch in greatest thickness; thus the ratio of the minor to the major axis of the arrow is 1 : 112. The two best shapes for arrows are considered to be the cylindrical, and the bob-tailed. The first is of the same diameter from the shoulder of the point to the feather, tapering from the fore end of the feather to the nock. The second, which Mr. Buchanan considers the best, tapers gradually off from point-shoulder to nock, having therefore an extremely 'fine run.' But greater length as proportional to thickness is probably to be found in the lances and javelins which have been used as missiles in ancient times, and among uneducated tribes. These weapons are instances of bodies of whose length great part is cylindrical, and which, nevertheless, do not suffer so much friction from the air as can countervail the diminution of its resistance that is effected by the development of their length.

Now it may seem a startling proposition, but it is one which I must maintain, that a javelin is the true type of the gas-vessel of an air-craft, in every condition that affects its motion, and that the hand that poises and throws the missile must be represented by the power-vessel which hangs from the float. The dart of Abaris, which he received from Apollo, and on which he flew round the world, is a true symbol of the future air-craft.[1] I shall show in the next chapter my reason for believing that there will

the rest of the system, placed in dock, and refitted, while the rest of the great sea serpent is floating quietly at sea. Of course the whole ship would never require to enter harbour; a fleet of our present little ducklike steamers would serve to take the goods and coals on board. The timid passengers who may prefer the water surface route to that through the bosom of the air or of the ocean, will have the additional advantage over the travellers in our present ships, that they would not be liable to sea-sickness. For the long vessel being always supported on the waves, never being tossed upon them, never mounting up or rushing down their declivities, would have no pitching motion, but would rush straightforward on its course, with but little variation whether the surface were smooth or rough.

[1] This famous instrument, however, meant something else besides. It is, of course, the compass needle.

be but little more difficulty in making a long thin gas-vessel support the power which is to hurl it, and the load which it is to carry, than there would be in hanging to an assegai, without bending it, the arm of the Kafir that threw it. Now there will be this other advantage in giving great length to the gas-vessel, that, although, as has been already admitted,[1] a long body is more exposed to the action of forces tending to derange its horizontal balance than is a short one, yet as the length increases, the effect of any such disturbing cause is diminished by a new opposition which is set up to encounter it. The liability to be upset is lessened by the fact, that the resistance of the air, and of its own inertia, to its turning about its shorter axis, becomes very great at the ends of the body, by reason of the velocity with which, and the distance through which, they would have to move in their revolution. Everybody knows how much more labour is required to turn a long boat than a short one, and how much the steadiness in flight of a missile is increased by adding to its length. The very resistance of the air to its motion tends to compel it to lie in the direct line of its course.

Now a cylinder of diameter equal to the minor axis of a spheroid, contains for equal lengths a greater bulk than any segment of such spheroid. Besides, a cylinder has this advantage in the building, that it can be made without any drawing of curves or 'cutting to waste,' with a rectangular piece of flat material. It will therefore be better to increase the length of the gas-vessel by inserting a cylinder between the curved parts of the spheroidal figure, than to add to the length merely by lengthening out its elliptical outline. This, however, will only be admissible so long as the addition of cylindrical length can be continued without exalting the friction of the air (if that should be found to operate) as rapidly as the cubic contents are increased. It will therefore be necessary to try a series of experiments with cylinders terminated by spheroidal ends, and to compare the results so obtained with those yielded by the compound ovals. In every case in which a figure made up partly of a cylinder is found to be equal in speed, with given propelling force, to a pure oval of the same length, the cylinder must be

[1] See page 135.

preferred, as having, when filled with gas, the greater buoyancy. I would propose, to simplify the conditions, that the length of every cylinder that is tried should be an exact multiple of its diameter, that is, of the common minor axis of the spheroids. The task of testing all possible figures that could be formed in this way would be infinite. All that could be done would be to select certain points of the scale for experiment. For instance, the slowest of the ovals, and any others at which the law of the reduction of resistance by increase of length might seem to change its ratio, should be selected for experiment, with the successive insertions of cylindrical lengths. Thus, extending to the cylinders the notation already adopted for the half-spheroids, representing their lengths by the number expressing their ratio to their diameter, such figures as the following would perhaps be tried:

1 | 1 | 1 . 1 | 2 | 1 . 1 | 3 | 1 . 1 | 4 | 1 . . . . .
1 | 1 | 2 . 1 | 2 | 2 . 1 | 3 | 2 . . . .
. . . .
2 | 1 | 1 . 2 | 2 | 1 . . . . 2 | 2 | 2 . . . . .
6 | 1 | 1 . . . . . 6 | 1 | 6 . 6 | 6 | 6 . 10 | 100 | 50

The middle figure of course represents the length of the cylinder, the outer ones the length of the hemispheroids.

Again, it might be useful to vary the experiments, by substituting for the half-spheroids, especially for the after one, segments cut from the ends of ellipses having a minor axis longer than the selected unit-measure. It might be useful to compare a few such figures with those of the typical form of equal length.

Further, it should be ascertained to what extent the aptitude for speed of the spheroids could be enhanced by adding to their beaks and tails conoidal caps of different forms. Finally, it should be ascertained by another set of figures laterally compressed like fishes, but of equal sectional areas and lengths with some selected spheroids, what are the relations of such figures to the solids of revolution, as respects the resistance of the air.

When a complete table had thus been formed of the results obtained with figures of a certain diameter, it would be requisite

to try another series of experiments with some circular discs, and with a few selected spheroidal forms of three or four larger sizes, for the purpose of learning how far the law ascertained for the smaller dimensions may hold good with the same forms on a greater scale. The minor axes of the new figures would of course be exact multiples of the unit diameter.

Finally, the case being thus made out for the diminution of resistance, a few experiments should be made in the other direction, to ascertain how the resistance of the air may be made the most of. The especial object of these latter experiments would be the satisfaction of our eleventh condition, for which we wish to get as firm a hold of the air as possible. We should learn from this enquiry, which would be made with saucer-shaped vessels of constant diameter and of various depths, to what extent it would be useful to make wings, that might be used for waftage, concave; and we should obtain a few hints for a future day as to the best forms of parachutes.

The number, then, of the experiments required is very great; any reader who may like an exercise in the reckoning of permutations and combinations may calculate the number. It must be remembered, too, that each result that will be noted in the tables will not be derived from a single experiment. The registered number will only be reached by a succession of tentative trials; and when the required degree of velocity is attained, the experiment will have to be repeated several times to check its errors or confirm its correctness. Now though this labour may be too great for any private individual to undertake, it would make but a trifling demand on the means of a wealthy and industrious association.

This, then, is the amount of work in this direction cut out for the 'Society of all Nations for the Promotion of Aerial Navigation.' Next as to the manner of it.

Having intended to commence a series of these experiments myself, I necessarily reflected upon the means of executing them. It may therefore be worth while to jot down what I thought of, and what conclusions I came to.

The subject divides itself into two heads: the first is the material of which the figures were to be made; the second, the

mode in which they were to be moved. As to the material, lightness was essential, and it was necessary that my experiments should be on a small scale. So I thought of vulcanised india-rubber, or paper to be stretched on a framework, gutta-percha sheet, cork, in succession, but found the difficulties of construction too great. At last I resorted to wood, which I had rejected at first on account of its weight. Accordingly I had a double series of hemispheroids carefully turned in alder-wood and polished. They were two-tenths of a foot in the lesser axis, and their lengths were from one-tenth upwards, each one-tenth of a foot longer than the one next below it. Each hemispheroid had either a peg or a hole in its base, so that they might be fitted together two and two in any pairs that might be desired. Now as for the manner of their motion. The most simple and compendious mechanism for this purpose is the form of apparatus used by Smeaton, by Robins, and by Hutton, in their experiments,—the whirling machine, with which the body being fixed at the end of an arm, which is made to revolve in a horizontal plane by a falling weight, travels in a circle. Now this instrument would give results comparable with each other for such short figures as were the subject of these old experiments; but with elongated forms such as I had to deal with, a circular motion would give results altogether false as referred to a path in a straight line, unless the diameter of the orbit was very great. So, when my whirling machine was made, I found that my spindles being attached to the end of an arm, not even nearly long enough to get rid of this error, and requiring for their counterpoise a considerable weight to be hung at the other end of the beam beyond the fulcrum, the weight of the system, and consequently the friction, was so great that the difference of the resistances to the motion of the different figures, which were so very small, was quite imperceptible.

A circular motion, then, was inadmissible, certainly with such bodies as I had prepared; and I had no means of trying them conveniently in rectilinear paths. On further reflection I concluded that my figures were much too small to be of any real use; and that if they were larger and of lighter materials, the diameter of any circular orbit in which they might be tried would

of course have to be larger in proportion; so that other difficulties in the construction of the apparatus would arise. A straight line, therefore, or one differing as little as possible from such, was the only path in which the experiments ought to be made.

On further reflection, then, I came to the conclusion that the experiments must be carried out according to some such programme as the following:

First of the material of the figures. Oiled paper is undoubtedly the substance. Its cheapness, lightness, readiness in construction, and the ease with which vessels made of it may be put and kept in shape by inflating them with air, fix our choice at once upon it, so soon as we contemplate making the figures of a good size. Let us suppose that the first series of experiments are to be made with figures of minor axis one foot in length. A set of spheroids must be made of oil-varnished paper,[1] all

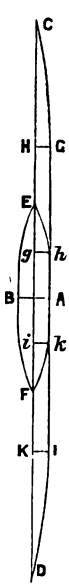
[1] Writing paper or good tissue paper will answer the purpose very well. A kind of paper comes from the United States, as the packing cover of newspapers and parcels, which would probably answer the purpose better than any other material. It is of a pale drab colour, and somewhat resembles in texture our common 'whitey-brown' paper; but it is of singular toughness and strength, and reasonably free from holes. Skilful workmen can cut the gores, and make the figures of this material very quickly. Mr. Darby, the well-known 'artist in fireworks,' of Regent Street, Lambeth, employs workmen who make paper balloons beautifully; the very same manipulation is all that is requisite in making these new figures. The only point that requires remark is the cutting of the gores. It would not be worth while to get the measurements of the gores by calculation from the lengths of the elliptic arcs, for which the formula is complicated and the process tedious. A sufficient approximation to the true form may be made in any case by the method recommended by Mr. Evans in 'Phil. Mag.' vol. xlvi. p. 326, and pl. 8. I shall here borrow his instructions, as the method is equally applicable to making models and full-sized envelopes, altering the words as may be necessary, and substituting for illustration the form of the provisional oval 2 | 4, for the circle of his figure:—'This method is derived from the obvious property that the breadth of the gore in any particular part is proportional to the chord drawn through that part parallel to the equatorial diameter.' The greatest breadth of the gore is first to be determined by dividing the girth of the spheroid at its minor axis by the number of gores intended to be used, and the length of the gore is to be ascertained. This may be done by two methods. Either by describing on

having this unit for their minor axis and major axis respectively one, two, three, &c. . . . . feet in length.

The spheroids must be strengthened from end to end by a cord cemented into each seam—one of these cords should be furnished with loops, for suspending the vessel when inflated. And round their greatest circular girth each must be belted with a layer of canvas, for the purpose of subsequently joining them together at this part in different pairs. All the perfect spheroids having thus been made, will be subjected in turn to the entire series of experiments. They will all then be cut in half through the plane of their minor axes, and will then be joined together carefully, two and two, into the compound forms 1 | 2, 1 | 3, &c., &c. This process of separation and rejunction will be repeated

paper on any scale the elliptical curve, by whose revolution a solid of the required form would be generated, by measuring the length of half the curve, from end to end, and finding the ratio which it bears to the major axis of the figure: the length of the required figure being known, the length of the gore will at once be given by this proportion. Or the length of the curve may be found by substituting for a and b their values in the formula for the elliptic quadrant, which is

Fig. 17.



$$1{\cdot}5708 \times a \left\{ 1 - \frac{1}{2^2} e^2 - \frac{3^2}{2^2 \times 4^2} \frac{e^4}{3} - \frac{3^2 \times 5^2}{2^2 \times 4^2 \times 6^2} \frac{e^6}{5} - \&c. \right\}$$

where $e = \dfrac{\sqrt{a^2 - b^2}}{a}$; a being the semi-major axis, and b the semi-minor axis of the ellipse. Let now A B (fig. 17) be the breadth, and C D the length of the gore thus found. 'On A B as a diameter describe the required shape A E B F of the model, or gas-vessel. Divide the curve F A E and the straight line D C into the same number of equal parts, and through the points of division h k, H K . . . draw the straight lines g h, i k, G H, I K . . . parallel to A B. Make H G equal to g h, and K I to i k . . . and through the points G . . . A . . . I . . . draw the curved line C G A I D, which will be one outline of the required gore.' The other outline may be drawn in the same way, or may be traced from the first curve by folding the material along the line C H K D. 'In the diagram I have divided F A E and D C into only four parts, for the sake of clearness: in practice, however, it will be necessary to make use of' a great number of divisions according to the length of the required figure, and the accuracy which is desired.

till the paper is worn out, or the series of experiments completed.

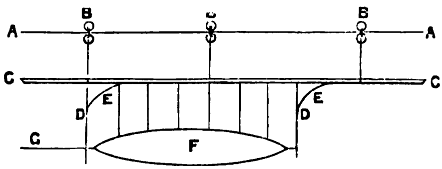
Secondly, as to the mode of experiment. The requisites are that the path should not be very different from a straight line, that it should be the same for all the figures; and that the velocity should be uniform during each experiment, at least during the whole time of observation. The readiest mode of effecting this will be to make the figures travel along a wire strained tight, so as to reduce the curvature of its catenary direction as much as possible. The points of attachment of the wire should either be on the same level, so as to make its mean direction horizontal, or the starting point should be considerably below the end of the course, so as to make the whole path uphill. In the first case the weight of the moving apparatus will assist in bringing the speed up to its maximum; in the second case this will have to be effected by a force specially arranged for that purpose.

It will of course be necessary to get as long a course as possible, for the double purpose of allowing plenty of room for the elimination of the first accelerated motion, and of getting as long a run as possible, for the observation of uniform speed. Of course the longer the duration of each experiment, the less the chance of error in observing the time. The length of the course ought to be limited only by the strength of the guide wire. It will be convenient that the extent of the run at uniform velocity, should be an aliquot part of a mile, to facilitate the adjustment of the speed, which will be observed by seconds, to the required number of hour-miles.

A light frame-carriage, consisting of three or more pairs of light-pulley wheels, enclosing the guide wire between their grooves, and having their sheaves united below by a light hollow cane, must traverse on the wire. From this rod the figure to be examined must be slung by threads, which are attached to the loops prepared on its back-bone cord. The beak and tail of the figure are each to be attached to a thin rod fixed, in a vertical position, to the lower side of the frame-cane. To this former of the two vertical rods the pulling line must be attached at such a point in its length that the traction shall be equally dis-

tributed to the pulleys and the vessel, so that the weight and the friction of the former, and the resistance of the air to the latter, should balance each other about that point, and not tend to twist or strain the suspension. A little practice will enable the experimenter at once to hit this point. The hinder upright rod must be fixed by a binding screw to the horizontal cane, so that its position shall be adjustible to the length of the figure to be supported. Fig. 18 exhibits the arrangement of the vessel in its carriage. A A, is the guide wire; B, B, B, the pulley-wheels; C C, the supporting cane; D, D, the head and tail rods, kept firm by stays, E E; F, the paper shell inflated, strung by its series of threads; G, the traction line. C C is to be hollow cane, for the double end of being itself light, and of receiving ballast weight within, for the purpose to be mentioned immediately.

Fig. 18.



The motion will of course be produced by the falling of a weight, that hangs from a cord wound on a small barrel, which, by a wheel and pinion movement, will drive another cylindrical barrel of very much larger diameter, which, as it revolves, will gather up the line G. The proportions of the radii of these wheels will, of course, determine the proportion which the pulling force at G bears to the moving weight. This force at G will of course be opposed, partly by the resistance of the air to the moving body, partly by the weight of the carriage and its load, and partly by the friction of the several parts of the apparatus. Since the variation of the former is what we wish to learn, and since the two latter foreign influences cannot be destroyed; the best way to simplify the results will be to reduce them to a constant quantity, by means of which their effect can be eliminated from the result. This will be effected pretty nearly by making the weight of the system that traverses on the wire constant.

In commencing therefore a series of experiments, it will be necessary to take care that the load borne by the pulley-wheels B, B, B, is always t e same. This will be best effected by estimating what will be the weight of the longest and heaviest figure that will be experimented upon; and by loading the carriage in every experiment exactly to a certain weight, which, to allow room for error in estimation, or for extending the experiments, should be at least the double of that so conjectured. The next course to be taken will be to try a complete series of experiments on the carriage alone, loaded up to the full weight. The weight will be in shot, and will be introduced into the hollow cane C C, so that no alteration in the ballasting will have any effect in altering the resistance of the air. The order of these preliminary experiments will be thus:—It will first be ascertained and noted how much weight at the primary axle is necessary, just to set the system in motion. The power-weight will then be increased till the carriage moves with a uniform [1] motion of one mile per hour. When this has been attained, the trial will be repeated three or four times to ensure correctness.[2] Weight must now

[1] It will be advisable to hang below the regulating power on the same cord, another weight, which falling at first through a short distance, and being then received on a support, shall help to overcome the inertia of the system, and to bring it speedily up to a uniform velocity; thus saving time, and relieving the power-weight of so much duty. Of course the results to be registered are only to be taken from the motion of the body through that part of its path which it travels over at truly uniform speed. A few observations will show at what distance from the starting-point the uniform motion is attained. If this distance is doubled, and the time of observation dated from the point so found, the results will be sure to be correct. By properly adjusting the auxiliary weight the accelerated motion may always be kept within the assigned bounds. There will in fact always be a slight acceleration of the speed, arising from the carriage being gradually relieved of the weight of the traction cord, as it is wound up; but if the cord is fine and light, this effect will be very small, and it will be constant for all the experiments; it may therefore be neglected.

[2] Of course the force might be fixed as the arbitrary quantity in each experiment, the velocity being the unknown quantity sought. And this would certainly be the simpler form of the experiment, as nothing would be necessary in this part of the operation but to hang a series of certain weights upon the moving axle, and to note the results. But, in this case,

be added to the moving power till the carriage runs at two miles per hour; and the same process as before will be gone through. This will be continued for every hour-mile up to the hundredth; where we may, for a few years perhaps, be contented to stop. When this series has been completed, a set of results will be obtained, in measures of weight, which will have to be deducted thereafter, as constants, respectively from the expressions of the force necessary to give the corresponding speeds to the several figures subjected to trial.

As soon as each figure is slung in its place for trial, it must be weighed together with the whole carriage, and care taken so to ballast the apparatus that it exactly counterpoises the standard weight appointed for the constant load. Each hollow shell will of course be filled to tightness with air, when under experiment, and care will be taken that it is quite tense before starting it for each run. Each will, of course, be furnished with a neck for inflation. This will be most conveniently situated on the front part of the figure, and should be a small oiled silk tube, about an inch in diameter, which, when the bag is blown tight, can be tied and tucked within the vessel; on the front of the root of this neck should be a small paper flap, which, when the body is in motion, will be pressed by the air against the side of the vessel, and, covering the cavity, will preserve the uniform surface of the figure.

Such, then, is this part of the question, and such the means of finding the answer, which probably will be that, by appropriately meeting it, the resistance of the air may be reduced almost to an infinite degree of submission on the one hand, and may be made to render us any amount of service on the other. The problem may be generally stated thus:—It is required to find the forms of least and of greatest resistance to the air. On the proper

the elimination from the several observed velocities of the retarding effects due to the constant resistances, would be a more complicated process than the simple subtraction of the series of constant weights in the method I have suggested. Again, the method of taking arbitrary velocities, and finding the forces, yields results in a form which is more suited to our practical end. For the question is not—given our power what speed can we get? but—given a certain velocity which we demand, what force must we find to produce it?

adaptation of these means—the active and the passive—and on the difference of their effects, the whole art will depend. We are here endeavouring to slip through the air; in a future chapter we shall endeavour to take hold of it.

Thirdly, I must repeat that, though, for convenience sake, I have here suggested provisionally the use of a slightly elongated, somewhat fish-like, figure for aerial vessels, I believe that the animal form that most nearly typifies that of the future rapid air-craft is that of the eel or serpent. And probably the cloth-yard shaft, whizzing from the bow of ancient English yew, gives the best prophecy of what their speed will be. Such shapes as that which I have adopted in my diagrams for illustration, will be reserved for the slow and steady carriage of ponderous burdens, at rates not much exceeding perhaps the deliberate paces of the express railway trains of the present day.

CHAPTER V.

CONDITION 3.—THE GAS-VESSEL MUST BE STIFF, NOT BENDING UNDER ITS LOAD.

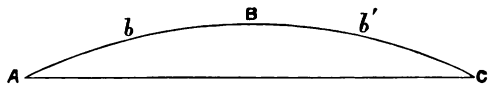
In putting together a number of parts, mutually fitting to each other, into any perfect whole, such as a complete circular arch, or a train of mechanism, it is hard to make good the claim of any one particular stone or link to be the unit of material, which enables the entire system to do its duty, and without which it would be impossible for the rest to work. I have called the propelling power the keystone of Aerial Navigation; because it has usually been the last element of success, which those who have laboured at building up the art have endeavoured to prepare, and because it is at once evident before demonstration that, without such provision, propulsion would be impossible. But it has scarcely been the absence of this requisite that has stopped the schemers in their endeavours to fly. If they had found all power ready at their beck, they would not have been able to make much use of it. They would have been kept back from success by the deficiency of a link in the chain of construction. This link is the means of making the gas-vessel stiff enough, when of proper length, to support its own weight, and that of the body suspended to it, without detrimental alteration of its shape. If the vessel could not be made rigid, it was of no use to make it long and narrow, and if it was not of such form, it could not be propelled with great speed. If, then, any one of our requisites could fairly be considered as more essential than another to the co-operation of the rest, that of stiffness might claim the distinction. I have already said that the fulfilment of this condition has scarcely been attempted by any who have speculated on the subject. Certainly none have even made a good suggestion to

this end, so far as I can learn. Many have not seen the necessity of the point. Those who have treated the matter most carefully seem to have despaired of attaining it.

Now this is most assuredly a problem in itself, which will require much careful experiment for its complete solution. For such experiments my object in this chapter will be to give some hints. If, however, I was not certain that I did not see before me the road, clear and straight, to success in this particular, I should not have ventured to treat at all of Aerial Navigation as a practicable art. In these days, when the art of mechanical construction is receiving such remarkable improvements, I have no doubt whatever that the suggestions which I have to make will be recognised as sound; and that, after a set of proper experiments, men who could run up the vast roofs of thin iron plate which may be seen at every railway station, the great beehive of iron rods and glass in Hyde Park, and the tubular bridges in Wales, would find it mere child's play to build gas-vessels of serpent shape, of any dimensions, measured either in feet or in thousands of feet, of the stiffness and strength of solid timber, and of the lightness of feathers.

Reader, did you ever see a good archer's bow strung? If so, did you ever try to bend it back, or to straighten it? If so, I do not think you succeeded. If the wood was not good, you may have broken it; but that was the fault of the material, not of the principle of its strength. It is this property of the bow which I

Fig. 19.

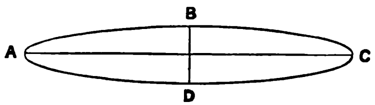


propose to use for the stiffening of gas-vessels. Fig. 19 is a strung bow, of proportions such that it would just include within its curve one half of the longest section of my provisional spheroid 4 | 8.[1] It will, I think, be admitted that if the arc A B C

[1] Curiously enough, I find after writing the above sentences, that the proportions of this spheroid happen to be exactly those of the best men's bows made by Mr. Buchanan of 191 Piccadilly, to whose courtesy I am indebted for this information. The depth of the arc measured from the middle of the strung bow to the middle of the string is $5\frac{3}{4}$ inches; the

be made of reasonably strong material, and the cord A C be strong, a considerable weight may be hung at B without altering the form of the bow, and that this will be more especially the case if the weight be distributed over a certain length of the curve, as from *b* to *b′*. However, if the curve be supported by a fulcrum at B, and weights be hung at A, C, the bow will be easily bent. If now a second bow be attached to the first, so as to be kept bent by the same string, but with its convexity in the opposite direction, as in fig. 20, the conditions of rigidity in the first direction

Fig. 20.



will not be altered, but the stiffness of the second bow A D C will now tend to oppose flexure in the other sense. The weakness of each bow will now be corrected by the strength of the other in the opposite direction. If, then, sufficient strength can be ensured in the material of which the bows (A B C, A D C) are made, the system will be perfectly stiff, in the plane in which the two bows lie (as in the plane of the paper); and will resist any forces tending to bend the bows, either by simple compression, applied at any two opposite points, or by acting on it as a lever at two outer points with a fulcrum between them.

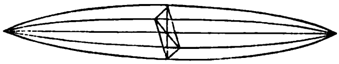
This principle of construction is somewhat similar to that on which the beams of balances and of steam-engines are made inflexible, in the plane in which they are subject to be strained. And the figure of our double bow is very like to the outline of these contrivances. The absence of elastic tension in, and the greater stiffness of, the material of which these beams are made, render the bow-string unnecessary in their case. We shall presently see that we shall be able to dispense with this cord in the apparatus which we are specially considering.

But the frame will still be liable to be bent in other directions across this, by forces acting as in planes intersecting that of the

length of the string from nock to nock is 5 feet 9 inches, which gives the ratio of the semi-minor axis to the major axis $\frac{1}{13}$ exactly.

paper; and the more nearly the direction of such forces coincides with that of a plane at right angles to the plane in which the bows lie, the more power will they have to bend them sideways. If now another pair of bows, of similar form and size, be applied to the same string, so as to be kept bent by it, and if they be made, by cords stretched from their mid points to the mid points of the first pair, to lie constantly in the plane passing through the strings at right angles to the plane of the first pair (as in fig. 21);

Fig. 21.



these will confer the stiffness, which they possess in the cross direction upon the former, which, in turn, will render them inflexible in the other sense. So that the system will now be inflexible in two planes passing through its long axis at right angles to each other. And, since it cannot be bent in any intermediate direction, without each of the two pairs of bows bending more or less in planes parallel to that in which the other is rigid, —for a bend in any direction will resolve itself into two partial flexures in directions at right angles to each other,—the system is stiff in all directions with respect to its longer axis. But materials and structures are never perfect; to compensate, therefore, for any tendencies to weakness in certain directions, we can add any number of pairs of bows in intermediate planes. Each of these must be stayed in exactly the same manner as the two first pairs. Each will, of course, not only correct deficiencies of stiffness in its own plane, but will add to the rigidity in every other direction. Thus by increasing the number of these arcs, we can obtain any degree of stiffness we desire, provided only that the elementary bows of which the system is made up, are not themselves pliable. The compound framework, too, thus

Fig. 22.

built up, will serve other important purposes, which I shall afterwards point out, which could not be so well effected by any

simpler contrivance. We have now such an apparatus as that of which one lateral half is represented in the diagram, fig. 21, and which consists of a set of bows strung by a common string, a point at the end of the lesser axis of each being tied to a corresponding point of its opposite fellow, and to that of its next neighbour.

Now we do not want, until they should prove to be necessary, to have any cords or stays within our gas-vessel. It will be best if we can construct a rigid hollow shell skeleton with all the elements of its strength at the outside, and with free room within. We may as well then, if we can, get rid of the bowstring and of the cords radiating 'from the middle at the thickest part,' of which cords B D, fig. 20, is one, and of which the purpose is to prevent any one of the bows from becoming further bent towards its present concavity. Now it will be at once seen that the radiating cords are no longer necessary; for their function will be supplied by the cord which encircles the whole set of bows, tying them together, each to the one on either side of it, at the extremities of their lesser axes. Now that the shell is complete, this girdle effectually prevents all the bows from being further bent, and the whole system from expanding, so that the short crossing stays may be at once removed. For now no one pair of the bows can be expanded further without straightening some other pair to a corresponding extent, and this is prevented by the bowstring.

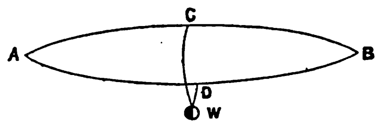
But we must also get rid of this bowstring. The forces which the longitudinal cord counteracts are pressures tending to crush the whole system together, to reduce its thickness to nothing, and to extend its length in a straight line to that of one of the bow rods. This contracting force acts with the greatest energy at the thickest part of the skeleton; where, indeed, the resultant of the whole force acting inwards upon each bow may be represented by a thrust in the direction of a radius of the great circle. Now it is clear that—if a rigid circle be placed within the skeleton in this plane, of such diameter that it will lie exactly within the bows, and of such strength that by its rigidity as an arch it will resist the inward thrust exerted by all the bows—the bows cannot contract, but must remain stretched. Now such a circle can easily be made, for the opposite forces of all the

bows being equal to each other, and uniformly distributed, will help to sustain the different parts of the circle against each other; and the more of them there are, the more support will they give to the arch within. If, then, this arrangement be made, the bowstring may be cast away, and the system will retain its form and strength, and if each bow be tied to the circle, at the point where it rests against the latter, the circle will supply the function of all the stays that had been used about the skeleton—of the bowstring, of the radial cords, and of the girdle.

I have considered the system as made-up elastic bows kept stretched, because the forces which would be acting on a gas-vessel made in this manner, and having a weight suspended about its middle, would be very similar to those acting upon a stretched bow. If we examine what the conditions of such a gas-vessel will be, as respects the strain to which it will be liable, and the directions in which it will require strength, we shall find that there will, at least, be no necessity for all the bows being elastic and tense. It is clear that if a gas-vessel of form such as that which we are contemplating had no weight hanging to it, and if either it were quite full of gas, or could be kept with its length in the horizontal direction, it would have no tendency to change its figure; and that therefore it would be unnecessary to furnish it with a framework of any considerable strength to keep it in shape.

But the case is very different with a loaded gas-vessel. Let A B be such a vessel. Let it be half full of gas. And let it be

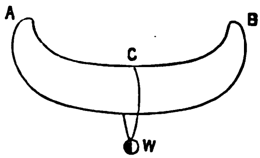
Fig. 23.



expected to bear a weight W, equal to the entire rising power of the gas, this weight being suspended by a cord W C, passing over the top of the gas-vessel, and brought down to W on the other side. Now it is at once evident that the point C being prevented from rising, A B will, if it be flexible, tend to assume some such form as that represented in fig. 24. Because the

light gas at A and B will have nothing to prevent it from rising but the weight of the vessel which contains it.

Fig. 24.



The forces then acting on the material of the upper part of the envelope, supposing it to be kept in form as at A C B, fig. 24, are very similar to those which would be exerted by its elasticity upon a bow-string, placed with its convexity upwards, namely, a lifting force at A and B and a downward force at C. On the other hand, the forces acting on the lower outline A D B, fig. 23, will be such as are exerted on a bow by the arms of the archers during the act of bending it.

These considerations show us exactly what resisting powers are requisite to be conferred on the two parts. A C B is already dragging on the system somewhat as if it were a tense bow; it therefore clearly does not require any more elasticity tending to straighten it or to reverse its flexure; it only wants to be kept bent, to have A and B tied down, and to have some strength given to it to resist downward pressure about C. A D B, on the other hand, demands elastic force to resist the tendency to bend it; if, then, A D B be made as a spring bow, having energy to resist further curvature, and if it be restrained from straightening itself by stays acting like the archer's string, it will keep itself in form, and will help to keep A C B too in proper curvature.

It is evident, then, that at least the upper bow of our skeleton need not be an elastic one, and that those on each side of it are likewise exempt from that necessity, the more decidedly the nearer they lie to the back-bone. It remains to be seen whether we cannot equally dispense with this quality in the lowest bow of the system.

If we replace our bowstring by a single rigid ring within the skeleton at its great circle, each bow must be equal in strength and elasticity to the one opposite to it, as its fellow in the pair; otherwise there will be a tendency to derangement of the symmetry of the system. If therefore we have only one ring, and A C B (fig. 23) is inelastic, A D B must be inelastic too. In this case then we must find some other way of keeping the figure in shape than that represented in fig. 22.

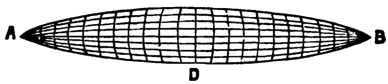
Now the weight w, hanging by the cord w c, carried over the gas-vessel, will act upon the latter with a tendency to crush it in; the same will be the case if the weight, instead of being hung by one cord, is hung by several that pass over the gas-vessel at different points of its length. The tendency is just as with a system of elastic bows, to press the sides together. This crushing force will be resisted to a great extent by the buoyancy of the gas, which presses equally in all directions upon all points at equal heights above its lower surface. But a certain amount of additional strength may be requisite to keep the vessel in shape under the pressure of the weight: this will depend partly on the extent to which the envelope is charged, and partly on the mode in which the load is suspended to it.

Further, it is quite evident that if, instead of concentrating all the strength of resistance of the skeleton in the ring-arch at its great circle, we relieve it of part of the duty, by furnishing the framework at several points in its length with other internal rings formed to withstand pressure from without, we shall have all the functions of the bowstring and other stays equally well fulfilled. And this result will be secured in a far more convenient manner; for not only will the framework be as effectually stiffened by this arrangement as by the former, but the whole of it, from end to end, may by this means be made equally strong to resist any force tending to crush it at any part. Besides this, the first ring, not now requiring to be so strong, may be reduced in mass, and the whole weight necessary for this part for the purpose of strength will now be distributed more uniformly over the whole length of the float; this will further diminish the tendency to turn up at the ends by loading them directly with a part of the burden which they must help to sustain. Again, with this construction, the elastic force with which the lower bow tends to straighten itself, and to distort the figure by giving a greater curvature to the upper outline, will now be powerfully opposed. For the top bow may be considered as a cord, strained over rigid rods, lying in the vertical diameter of the rings. And the lower bow cannot be straightened without stretching this cord.

It may here be mentioned that the tapering of the vessel towards each end, which will, of course, be favourable to speed,

whatever may be the exact curve that is adopted, will lessen the tendency to turn up at the head and tail. For the quantity of gas in each segment of the length of the vessel, as cut off by planes parallel to the minor axis of the figure, at equal distances from end to end, will be less the farther it is from the centre, in the ratio of the cube of the radius at each point; while the weight of the shell that contains it will be diminished only in the ratio of the square of that quantity. So that the farther the gas is from the minor axis of the figure, the less it will be in quantity, and the more it will be loaded in proportion to its bulk; and therefore the less tendency will it have to rise. Again, the rigidity of the shell itself may be farther helped in its resistance to this distorting tendency, by distributing the whole burden as much as possible along the whole length of the gas-vessel. I have already shown [1] that this must not be done by suspending the propelling vessel by cords diverging to the ends and other parts of the float. How it may be done I must not discuss here, but in a chapter appropriate to the subject. However, let us now see how far we have got in the construction, and what are the qualities of our skeleton. It will be such a framework as that of

Fig. 25.



which one side is shown in the diagram fig. 25. The stiffness which it is required to possess is such that it shall maintain the straightness of its long axis in spite of forces tending to turn up its head and tail. There will not be impressed upon it any disposition to curvature laterally, or in any other direction, if the burden be properly slung to it. It must also be able to resist any pressure that may tend to compress it sidewise, or to crush it endwise, so as to shorten it. These last two points will be secured by the joint action of the rings and bows, and by the resistance of the latter in the direction of their lengths. The tendency to lateral compression will, as I have stated, be due to the weight of the suspended load; but that it cannot be consider-

[1] See pp. 41–54, above.

able, if the vessel is at all fairly charged with gas, will be evident to anyone who has seen how well a balloon maintains its rotundity when not much more than half full, notwithstanding the weight that hangs from it. There will be very slight tendency to compression lengthways; and this will be considered in the next chapter. The only strain, which we are now combating, is that tending to turn up the ends.

Now, if the gas-vessel be of a very short shape, such as the provisional spheroid which I have taken for illustration, and if the weight be distributed over the middle third of its length, the ends, if the material were good, might easily be made stiff enough without any further complication of the structure, especially with the aid of the elasticity of the lower bow. For it will be seen that the vertical section of the ends, taken through the long axis of the vessel, approaches to the form of a triangle, and may be considered as bounded by such a figure made of rigid rods. And everybody knows that a triangle of rods forms a perfectly inflexible framework if the material is practically stiff, for such length as that of the sides of the triangle. Again, by multiplying the rings, the framework of the ends may be divided into a number of figures, virtually equivalent to so many triangles, the length of whose sides must be less, the greater the flexibility of the material of which the bows are made.

But if the gas-vessel be of a long arrow form, which I beg to be understood as advocating, this arrangement would be insufficient to secure rigidity. For, in the first place, it would be extremely difficult to give any such tension to the lower part of the surface, by the mere elasticity of its bows, as would enable it to contribute much to the stiffness of the system. Again, a great part of the length of the figure would be now cylindrical, or of a form differing but little from a cylinder. Now it might be impossible to distribute the burden fairly over the whole of this part of the gas-vessel, so that the free extremities would not present a section approaching to the triangular. In such case a part of the gas-vessel towards each end, beyond the outermost points to which the weight is slung, would be represented in section by a parallelogram, which, of course, is a flexible system. We must, then, give to our skeleton some further resources of stiffness.

Let now fig. 26 represent in elevation a part of such a cylinder, made of materials not in themselves perfectly rigid. It is evident that the stiffness or flexibility of the entire figure depends upon that of each of the small rectangles of which the shell is composed. But a parallelogram admits of change of form to any extent between the limits within which the joints can move. In our case the limit will be that of the flexibility of the material of the longitudinal rods, the pliancy of which will give to the whole framework the same sort of mobility as that which a parallel ruler derives from the freedom of its joints. There will be nothing, so far as this part of the framework is concerned, to prevent it from assuming some such form as that

Fig. 26.

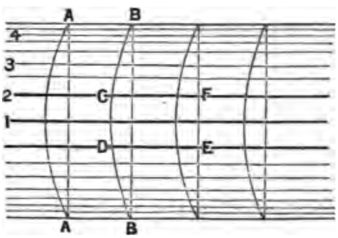
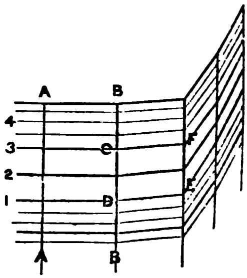


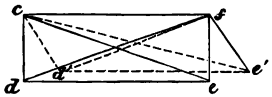
Fig. 27.



represented in fig. 27, supposing the part between the rings A B to be kept stiff by the weight hanging to them, and the part to the right of B to be at liberty to bend upwards. The only resistance offered to the force tending to produce this flexure will be any stiffness which the material of the long rods, 1, 2, 3, &c., might possess, and the inflexibility of that part of the end of the vessel where the curvature might be sufficient to amount to a virtual triangularity of the framework. This latter would have some slight effect in opposing the flexure of the cylindrical part, because no part of the system could be bent without altering the form of the ends more or less; but they would, of course, be unable to bear, without risk of rupture, the strain that would be thrown upon them by any considerable bend of the more flexible part of the skeleton.

We must, therefore, provide other means of giving stiffness to the whole framework. This is, fortunately, a very simple affair. The flexibility of the cylinder depends upon the play of the elementary parallelograms, of which its shell is made up. Conversely, if these can be made rigid, the whole framework will become perfectly stiff. Now, everybody knows that the two diagonals of a rectangle are equal to each other, and that those of no parallelogram of which the angles are not right angles can be equal to each other.

Fig. 28.

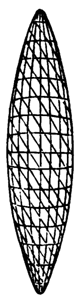


Let, now, c, d, e, f (fig. 28), be one of the elementary parallelograms of our cylindrical skeleton; for instance, the one marked by the same letters in figs. 26, 27. Its diameters, $c\ e$, $d\ f$, are equal to each other, and it is evident from the property of the parallelogram just mentioned that the figure cannot be shifted into any new position, such as c, d', e', f, without the diameters ceasing to be equal. Indeed, this change cannot take place, as is easily proved, without shortening one of the diameters and lengthening the other. If, then, the opposite angles of the rectangle be tied together by strong cords which will not admit of extension, it is clear that the parallelogram cannot alter its form, because its sides cannot take any new position without lengthening one of the diagonals. But, in the case of our gas-vessel, the tendency to distortion, which we are endeavouring to counteract, will only be acting in one direction at each end. It is, therefore, only necessary for this purpose that one of the diagonals, namely, the one that runs upwards and endwards on each side of the part where the downward force is acting, need be supplied in each of the parallelograms. It may, however, be better to brace the skeleton in both directions to give it strength against any accidental force tending to bend it in the other sense.

If, then, all the elementary parallelograms of our skeleton are firmly fitted with diagonal braces on this principle, it is clear that the whole figure will be perfectly stiff, whether it be cylindrical or tapering. The more it approaches to the cylindrical form the more it will require this bracing, and if it be tapering it will still

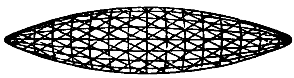
derive additional strength from this mode of construction. This is exactly the principle on which great girders for bridges are put together, and on which the stability of the splendid structure in Hyde Park depended. Since, however, we need only provide for stiffness in a vertical plane, just as is chiefly necessary for bridge-girders, we might omit the diagonal braces on the upper and lower parts of the figure; for in those parts the parallelograms will suffer less and less alteration of shape in the bending of the figure, the nearer they lie to the very top or bottom of the frame. The parallelograms between the side-ribs will sustain most of the distortion; and on their diagonal braces will mainly depend all the stiffness that can thus be conferred upon the system. But it will be well not to dispense with them in the other parts, for they will contribute generally to the strength of the figure, and in the upper part especially will help to sustain the envelope against the upward pressure of the gas.

Fig. 29.



So our skeleton gas-vessel now presents either the appearance shown in diagram, fig. 29, or that in fig. 30, according as the parallelograms are braced in one or in both diagonals. And its stiffness will now depend but little upon the stiffness of the materials of which it is built, but chiefly upon their strength to resist rupture. If, too, materials can be found of sufficient strength to bear the strain, notwithstanding that their rigidity, taken alone, may be slight, vessels may be constructed in this way of very great length, yet well able to retain their form.

Fig. 30.

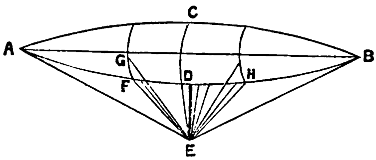


But there is yet another mode of further enabling the figure to resist the distortion to which the gas lifting at the ends and the weight dragging down the middle will tend to give rise. This is the old principle of the stay, so indispensable in naval engineering for giving strength to the masts. This artifice in construction has, no doubt, at least as wide a duty to fulfil in aerial architecture as it has had in marine. Sir G. Cayley long ago[1] pointed out the utility of stays and braces in one branch of

[1] Nicholson's 'Journ.'

our art, namely, in the extension of kite and wing-surfaces, but he does not seem to have contemplated making it serve this fundamental requisite of ensuring length in the gas-vessels. Its application to the present purpose is extremely simple. Let D E (fig. 31) be a light stiff rod firmly attached to the bottom of the

Fig. 31.

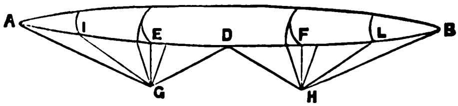


skeleton about its middle or at its thickest part; and let it be secured in its place by stays, E F, E G, E H, etc., running from its lower end to certain parts of the body of the gas-vessel, not far from its base, as the mast of a ship is fixed by its stays. It is quite clear that the cords E A, E B, will, if the longitudinal ribs of the skeleton are strong enough to resist a slight tendency to compress them endwise, oppose to the up-turning of the ends a resistance limited only by the strength of the cords and of the mast D E. Of course any number of intermediate stays may be stretched from E to other points of the gas-vessel between E D and E A or E B. The tendency of the two ends to distortion will, in fact, neutralise each other. The greater the length of the gas-vessel, the greater must be the length of the mast D E, to enable it to give resistance to the ends A B. I shall, however, hereafter in treating of the mode of suspension of the boat or man-vessel, show how, in the case at least of short gas-vessels, such as our 4 | 8 spheroid, another part of the apparatus may be made to answer the purpose of the sprit or mast, as a sustainer for the stays.

But if the gas-vessel be of very great length, it may be difficult to make the mast E D long enough for this service without increasing its size and consequently its weight, for the purpose of conferring on it sufficient strength to free it from liability to fracture. However, this same end may be secured by increasing the number of masts, and placing them at proper intervals along the length of the gas-vessel. For instance, let A B (fig. 32) be a

gas-vessel constructed in the manner I have described, and of such proportions that its length is twelve times its greatest thickness, being made of two half-prolate spheroids and of the

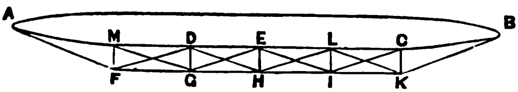
Fig. 32.



form that would be represented in the notation I have adopted as 8 | 16. Let D be the point of its lower outline, that lies exactly under its centre of buoyancy, and let the weight be distributed longitudinally over a portion of the gas-vessel equal to one-third of its length, D being the middle point of the length so weighted. Let E F be the lower outline of so much of the vessel. All that portion of the gas-vessel that is bounded below by E F will of course be sufficiently stiff, being kept so by the weight which is attached to it. The end-limbs E A, F B, are all that can require to be furnished with additional means of rigidity. These may be stayed down by cords, A G, I G, B H, L H, exactly in the same way as was indicated for the shorter vessel, to the two rods, E G, F H, fixed at the boundaries of the stiffer part of the system, these masts being braced back to D or to any other points between them, or to the extremities of each other.

Further, these masts and stays may be multiplied along the whole length of a very long arrow-shaped gas-vessel, as represented in fig. 33. The masts will, of course, be required to be stayed sideways to give them strength; I have not represented the side-stays in the diagram, as they would complicate the sketch. It will be seen that these interlacing braces, F D, G M, D H,

Fig. 33.



G E, etc., must give to the skeleton all the stiffness in one direction of a long girder. The system will be further strengthened by the addition of a longitudinal cord, F G H I K, stretched along the

lower ends of the masts, and fastened to each of them. In fact, the herring-bone system of sprits and stays running along the belly of the vessel may be considered as a great girder-beam, having to perform exactly the same function as one of the compound beams that supported the roof of the Great Exhibition building. It may be considered as a girder resting on the gas or on the air at A and B, and having to support a share of the weight suspended at D E.

The gas-vessel thus constructed is represented in section by fig. 34, C A D being the vessel itself, A B being the sprit, B C, B D, the side stays. The same amount of firmness might be given to the uprights by separating each rod, as it were, into the two sides of a triangle, as in fig. 35. In this mode the stays would be dispensed with, and the props A B, B C, would have an advantage in their mode of fixing them to the framework, for they would admit of being bound by their feet, which would bend outwards to the ring-ribs of the skeleton, side to side, whereas A B, standing vertically on the ring, could not be so securely, and at the same time so simply, fastened in its place.

Fig. 34.

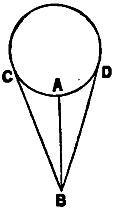
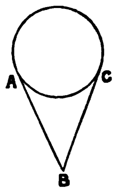


Fig. 35.



It might be found advisable to stiffen the vessel in the other direction, so as to prevent its ends from bending downwards, and from causing the back to bow upwards; but this could only occur if the vessel were charged with but a small proportion of gas, and had a weight hung to its ends. This purpose would, of course, be secured by fitting the vessel with an exactly similar system of sprits and stays along its upper side. Of this latter application of the stay principle on the top of the vessel, a hint may be seen in the plates of Meusnier's proposed eggoon, given in M. Monge's work.[1] But what useful purpose they could serve in this short vessel is not very apparent. M. Jullien, too, as would appear from the sketch of his long gas-vessel in the French newspaper,[2] seems to have had some stays about his

[1] Monge, 'Études,' Pl. vi. vii. viii. ix.

[2] 'L'Illustration,' November 15–22, 1850.

apparatus, but in the print they are represented on the top of the vessel, just where they would be of least use. There is no sign of girder braces for keeping the vessel stiff, to resist the distortion which its own buoyancy would entail upon it; and without these his beautiful apparatus would certainly be useless in practice.

When the gas-vessel is made of metal plate, or of other material in similar form, possessing a certain degree of stiffness, such as gutta-percha, etc., it may, of course, be furnished with the sprits and ties, in the same girder fashion that I have described as specially suited to strengthen the bamboo framework. But another mode of stiffening is specially applicable to structures built of plates. They may be furnished with a keel or backbone or both, made of metal plates riveted or otherwise fastened together so as to form tubes of rectangular section, which may be further strengthened by dividing them into cells along their upper sides, which would have to sustain a thrusting or crushing force. This is the famous device applied by Messrs. Stephenson and Fairbairn to the stiffening of the great tubular bridges, and by Mr. Fairbairn to giving strength to the arms of cranes for lifting burdens;[1] and it will, no doubt, be extensively used in locomotive aerial architecture, as it has been successfully applied by these great poets in the stationary branch of the same art.

This method, then, I believe will afford a complete solution of the problem of stiffness. The braces and sprits will, of course, add something to the resistance of the air to the vessel at high velocities; but this will be very slight, for the rods will be but thin, and may be broad in the direction of the length of the vessel and narrow towards its width; this form will give them greater strength in the direction in which they will require it, at the same time that it will diminish the resistance of the air to their progress.

I now come to the question of material. Having occupied so many pages in the treatment of the method, I shall not give much space to this part of the subject. A few words, indeed, will give one answer to the question—What is all this to be built of? Bamboo and metal wire. Zinc iron wire for cheap rough-

[1] 'Mech. Mag.' vol. liv. p. 382.

working vessels; steel gilt for the dandy craft that will carry her Majesty's mails to all the islands of the world. The varieties of the bamboo which grow in many parts of the world, have been through countless centuries doing much service for the Chinese and other nations whom we regard as our inferiors. Multifarious as are the uses to which this magnificent product is put in China, they have not, probably, yet found for it its true destiny. The hollow cane is a vast natural quill, of which flight is, I think, quite evidently the true and appointed purpose. It probably combines lightness with strength in a greater degree than does any other structure or substance in creation. The rattan or solid cane will probably also, by virtue of its toughness, find its uses in aerial architecture.

The longitudinal ribs of our gas-vessels will be made of bamboo rods, of such thickness as may be required, and bound together end to end accordingly. Marine glue, of course, will lend its aid in making joints. Bamboo rods may be had of any thickness, I believe, from two feet to two lines in diameter; but they are so little used as yet in this country, that we may be said to know almost nothing about the extent of their capabilities. The same material will, of course, furnish the strong rings which are to support the framework against lateral pressure. For this purpose in the larger vessels they will probably be bound together in bundles, and perhaps further strengthened with metal tubes. If the bows or longitudinal ribs have not much spring given to them, with a tendency to contract the breadth of the vessel, the rings may be put on upon the outside as hoops, to which the ribs must be firmly tied within at every crossing. The cross bracings of the parallelogram-spaces between the ribs will be of the lightest and strongest cord that can be got. Wire and wire-string will claim to serve this end, perhaps rattans may be used for this purpose. The projecting sprits and stays for stiffening the whole will, of course, be of bamboo, and of wire-rope or silk, or other fine strong cord.

It must be remembered that at the upper part of the gas-vessel there will be a strong outward pressure exerted by the gas; while at the bottom the weight hanging to the vessel will have a certain tendency to crush the sides together. This indicates that the diagonal bracings of the parallelograms must be

made as strong as possible at top, and supported by girth-cords running directly across the top, binding the bows together. At bottom the circular ribs or rings will require to be strengthened, to enhance their outward resistance, and to enable us to keep the bow-rods apart.

No doubt the reader is saying—'But all this weighs heavily—is a monstrous tax on buoyant gas.' Undoubtedly it is; but it is absolutely necessary, and more weight, too, to which I have not yet alluded, must be added to the gas-vessel—our art is hopeless without it. Besides, I must ask the reader to remember that a balloon-net is no slight weight, and yet, being necessary for balloons, it is used. The stiff framework is to supply the place of this flexible apparatus; it is, in fact, a rigid netting instead of a pliable, a heavier one certainly. But again I must remind the reader that, with the necessity for this additional weight, the power of sustaining it is increased; and that the more this stiffening framework is extended, the more capabilities has our vessel of buoying it up, and that without any increase of the resistance of the air. For, as I have already insisted, every addition to the length of the gas-vessel is not only probably so much added to the aptitude for speed, but an undeniable clear gain in lifting power of the whole buoyancy of the gas contained in the additional length. Of course, the first duty of the floating power so obtained is to lift the vessel which holds it. If for every elementary portion of the length of the gas-vessel (except at the very ends, where this cannot hold good), the weight of the shell is less than the difference between the weight of the cubic contents of the same length of it as hydrogen and its weight as air, the vessel will be buoyant, and the residue of its floating power may be applied to neutralising the weight of an additional burden. But more than this is necessary, for the vessel must be able to rise to great heights in the air without loss of gas, which must therefore have plenty of room for expansion within the vessel. So the cubic contents must not be taken as the measure of buoyancy, but only a fraction of them, which will be determined by the height to which it may be desired to be able to rise.

I do not attempt to give any calculation as to what the weight of such a gas-vessel as I have suggested would be, because, firstly, it must be heavier yet, there is more to be added to it; secondly,

I do not know the weight of the most important material concerned, in relation to its strength, viz. bamboo.[1] There are, in fact, no data for such a calculation; and this is just one of the points with respect to which a number of experiments are required. If in any case a gas-vessel when made should be found not to be quite equal to the weight it was intended to carry, or if it should at any time be desired to increase its lifting power, all that will be necessary will be to cut it in half, and to add to its length by letting in a cylindrical piece of the diameter of the section, and of length sufficient to confer by its bulk the requisite floatage. This no doubt will be done every day, and it will be a far simpler process than the lengthening of a ship, which is frequently found necessary.

I presume that the reader has gathered, if he has followed me through this network of canes, that I propose to enclose the envelope or gas-vessel proper within the skeleton framework, which I have been describing. I would have the gas-bag itself perfectly flexible, and usually[2] of such shape as to fit, when fully inflated, exactly into the cavity of the frame-shell; which, so far as we have yet seen, has for its special function that of providing a right support for the burden. To prevent the envelope as much as possible from shifting its position within the shell, I would tie it at each extremity to the skeleton, not so as to throw any strain upon the texture of the envelope, but thus: Let a strong cord of exactly the length of the long axis of the

[1] I have only had the opportunity of weighing one long piece of bamboo, which, I was informed, was of the variety called 'North Carolina cane.' It was smooth on the outside, with no projecting knots at the joints. It was twenty feet long, tapering from about a tenth of a foot in diameter at the butt end, to about two tenths of an inch at the smaller end. It weighed 1 pound 10 ounces avoirdupois. By weighing several short pieces of another variety of hollow bamboo which I was told was called 'Malacca cane,' I found, by taking the mean, that this sort, when about ·07 ft. thick, weighs about 800 grains for every foot of its length, including the knots, where it is not hollow. So that, supposing its thickness uniform, a piece about 8¾ feet long would weigh a pound. I find that of common rattans, which however vary much in thickness, about thirty feet in length weigh a pound.

[2] I shall hereafter have occasion to suggest some modifications of the arrangement of the gas-vessel, in which the envelope will not be a single bag just fitting the outer shell when full.

inflated envelope, or a little less, pass through it from end to end, and through the material of the envelope, at the extreme points at which the cloth or other texture must be fixed to it, airtight. The envelope being now placed within the shell, the two ends of the cord should pass through holes in the extreme points of the shell, and the head of the envelope being drawn up to the head of the skeleton, should be secured firmly in its place. The other end of the cord at the stern point being hauled tight, the other extremity of the envelope will be pulled up to the end of the skeleton, and the rope being kept stretched will not only keep the envelope in its place without putting any strain upon the texture, but itself acting as a string to all the bows of the frame, passing as it does through the axis of the vessel from end to end, will help, if the bows have any elasticity, to give firmness to the whole structure.

However, when the vessel is very long, it may be convenient to have more than one gas-bag in the interior of the frame. This arrangement would serve the double purpose of preventing the gas from all running to the end of the system in case of a pitch or plunge of the vessel, and of enabling the stiffness of the whole structure to be further secured by internal bracings at the part between the gas-envelopes.

It is possible that it may be found convenient to build the skeletons for gas-vessels of large size of metallic tubes instead of bamboo. For the larger the scale of the structure, the less is extreme lightness essentially requisite in the materials. This brings me to a point on which I have before had occasion to touch.

I spoke, in my chapter on the envelope-stuffs, of making the outer covering of the gas-vessel of metal plate.[1] This to a certain extent anticipated a part of what I have to say here. For it is evident that, if the entire shell of the gas-vessel were constructed of such solid material, a very considerable degree of stiffness would be already secured; all that would be necessary in such case would be to strengthen the metal with a few ribs and hoops, and with a good system of herring-bone braces and stays along

[1] See p. 200, above.

its lower side. Within, there would be no envelope, but a horizontal diaphragm attached all round to its equatorial line. The same remarks apply of course to gas-vessels made of any other rigid texture, such as gutta-percha or pasteboard. A shell made of such materials as these may be said to contain within its own substance the braces and ribs, by which we endeavour to give to a skeleton structure the firmness and stiffness of a continuous texture. But these solid tissues, such as plates of metal and gutta-percha, &c., must be very thin, that they may be sufficiently light; and then their strength of rigidity becomes much reduced. Experiment only can decide in what proportions of size and thickness the materials to which I have referred can be used. Experiments were necessary to ascertain how the tubular bridges were best to be built, after the material and the chief principles of structure were settled.

This, then, explains how I would secure stiffness for the gas-vessels of air-craft to be navigated with boats. For the simpler case of solitary flying, the mode of structure admits of, and perhaps requires, considerable modification. In the first place, such extreme velocity as will be demanded for air-craft proper, at least for those intended for human transit, will not be generally sought by gentlemen enjoying the exercise of flight as a recreation, or by travellers on a flying tour. Therefore such strength will not be essential in the structure of the floats for this purpose. In the second place, since it will be desirable to have the apparatus as small as possible, it must be made in the simplest and lightest manner, that it may be buoyant when filled with hydrogen, without being of any very great size. Again, the reduction in size is favoured by these considerations:—Firstly, no extra weight will be required for maintaining the balance of buoyancy, for the flights will not be required to be of great length, so that variations in this respect need not be guarded against; secondly, the whole weight being suspended by itself, and not liable to shift, the balance of level will require no contrivance for preserving it; thirdly, it will not usually be requisite to mount to any considerable height in the air, so that the gas-vessel may be charged nearly, or quite full, at starting, and no extra size and weight need be given to it with the view of allowing for expansion.

I would propose in this case, neither to have an outer shell for stiffening, nor to make the envelope itself of rigid materials; but to make the gas-vessel of flexible material, such as oil-gummed linen, or caoutchouc silk, and to stiffen it in the manner I will now proceed to describe. The common umbrella embodies all the further hints for this purpose which are not provided by the bow and string, to which I have already referred for illustration. I would build my envelope upon a framework which, being within it, should give it all the stiffness and firmness requisite for the duty it has to perform.

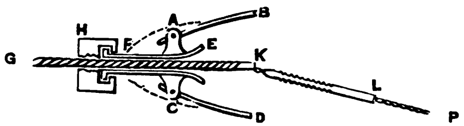
The skeleton should consist of a set of flexible bows of light cane, of whalebone, or of steel, arranged in a manner similar to that represented in the diagram, fig. 21. Their extreme ends should be jointed like the ribs of an umbrella on hinges in a strong wooden or metal disc, one for each of the two sets of ends, just large enough to allow the bows to move freely without interfering with each other. To the centre of one of these hinge-discs must be fixed one end of a wire-rope, or other cord, strong enough to keep all the bows curved, and longer by some feet than the bows when straight. The other hinge-disc must have a hole through its centre, and in this hole must be fixed a strong metal cylinder tube about a foot long, a piece of gun-barrel for instance, of calibre just sufficient to allow the long bow-string to pass freely through it, polished on its concave surface, and slightly bell-mouthed at its inner end. The free end of the bow-string being passed through this tube from the inner side must be pulled, while the bows, which must not require much force to bend them, are drawn outwards about the middle of their length, to make them convex. The cord must be tightened up till the bows are so far bent as to form, between the deepest points of each pair, a breadth equal to the intended thickness of the gas-vessel, and must be fixed at such length to the tube end of the framework. These bows must then be bent to the curvature of the intended figure; any required curve may of course be given to them by thickening them, or reducing their substance and so altering their stiffness, at any given part of their length. When they are once properly adjusted in this manner, they will of themselves take the required form at any future

time as soon as they are strung. When so far prepared, each must be symmetrically tied to its next neighbour by strong cords, at points taken at certain regular distances along the length of the figure; so that each such cord being continued round the whole figure, and tied to each bow at the point where it crosses each, shall form a circular girth, preventing the entire system from expanding beyond the limit so prescribed, and keeping each rib at the proper distance from those on each side of it. If another set of diagonal cords be added, as in figs. 29, 30, additional strength and stiffness will be given to the frame when strung. When the bows are extended, these cords will be loose and will have no effect on the system, but when they are bent they will act as hoops maintaining the whole in form. The bow-string will keep the system up to its convexity; the girths will prevent it from exceeding the proper curvature. Next the bow-string must be cut, just at the point where it enters the tube from within the skeleton, and the two ends so formed must be attached each to one end of a metal rod, about two feet long, and of such thickness as just to pass through the metal tube in the nozzle of the frame. The fore end of this rod must be a little conical, and its fore half should be topped with a screw, and the after or inner half should be perfectly cylindrical, and polished so as to fit the tube, as the plunger of an air-pump fits the barrel. Over the outer end of the tube must be a perforated cap or nut, which turns freely on the tube, but has on its inner surface a screw thread which exactly fits that of the rod. The free end of the bow-string being now passed through the tube and nut, and being hauled up till the beak of the rod passes out through the nozzle tube, the nut being turned will secure it at once, and by screwing up the nut, the string may be drawn tight, and the whole framework made firm.

The structure of this apparatus is represented in section in fig. 36. A B, C D, the ends of two of the bows, with their hinge-joints at A and C on the hinge-disc A C. E F, the tube bell-mouthed at E to favour the entrance of K L, the stopper-rod, which is screwed towards K, polished towards L. G K, L P, the bow-string, H the screw-nut. The uses of this part of the system will be evident presently.

The bow-string being now hauled tight, the rod screwed in its place, and the whole skeleton thus locked into rigidity, the

Fig. 36.



gas-vessel must be built upon it. This may be done of course in a variety of ways. The best, perhaps, would be (supposing the envelope to be made of linen-web varnished with linseed oil-gum, or of gasproof silk) to make the walls of the vessel in as many longitudinal gores as there are bows, and to arrange the seam between each pair of gores along the line of one of the bows, to which it should be attached throughout its whole length. This latter part of the construction will require to be done with care, to avoid throwing any strain on the texture; this may be secured in a variety of ways, which need not here be mentioned. The only points that require notice are, that the beak of the envelope must be carried over the hinge-plate A C, where it must be strengthened so as to protect it from chafing, and down to the tube F E, to which it must be closely joined all round, so as to be perfectly gastight; and that the gores should be of double thickness at the part which is intended to be the upper side of the vessel.

It will now be seen that when the envelope is full, and the frame set, the rod K L, fitting tightly into the nozzle tube F E, which, of course, will be well oiled and luted, will form a perfect stopper to the vessel. Care would have to be taken that no air entered at the nozzle while the vessel was being filled with gas; for of course the bows would only be expanded gradually as the gas is poured in. This, however, will be very easily managed in a variety of ways, for instance, by keeping the nozzle under water, or by attaching to it a hose which shall be filled with water, and through which the end of the bow-string shall pass.

One of the advantages of this mode of construction for small vessels will be, that the whole apparatus, when out of use, can be

compressed into the form of a long thin package, of the length of the straightened bows and of the thickness of the folded envelope. Such a vessel, when full and tight, would exhibit an appearance precisely similar in kind to that of a stretched umbrella. Of course, the same mode of construction is equally applicable to vessels for associate rowing, or for mechanical propulsion. Indeed, I would recommend that the first experimental vessels, which it would be desirable to build as cheaply and as small as possible, should be built in this manner. By this method sufficient stiffness will be given to vessels of no great length, and, as will appear hereafter, some of our other requisites will be equally satisfied by the same arrangement. Some additional appliances will be necessary to enable the vessel constructed on the umbrella-bow plan, to support a burden suspended to it. But this will be more appropriately considered in another place.

The way is now prepared for the consideration of our next condition.

CHAPTER VI.

CONDITION 4.—THE GAS-VESSEL MUST BE FIRM, NOT YIELDING TO THE PRESSURE OF THE AIR.

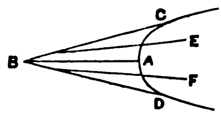
THE tediousness of the last chapter will be somewhat compensated by the brevity of the present one, of which, indeed, the chief work has been done in the pages just concluded.

In the case of the envelope stretched upon a skeleton framing, nothing more need be said; the head of the vessel is, of course, as soon as the bows are bent, as firm as the material will admit of being made, and ready to face without yielding any resistance which the material is strong enough to withstand.

If the gas-vessel is made of solid materials, such as metal plate, gutta-percha, or papier-maché, of course the same property of firmness is equally secured for it, without any further arrangement. For the head of the vessel will, whatever be its form, be of the nature of an arch or vault, calculated to meet any external pressure in the line of the axis of the vessel, with the most effectual resistance.

Should the bows ('*bovs*,' I mean, not '*bωs*') of the vessels built on either of these fashions require any further strengthening, it

Fig. 37.



may be given to them thus. C A D (fig. 37) being the curved outline of the prow, A the extreme end of the long axis, let A B be a sprit fixed at A, and let stays B C, B E, B F, B D, radiate from its end B, to points symmetrically arranged on a circle girdling

the head of the vessel about the part where it requires support. To these points the stays must be firmly attached. They must be furnished with one of the hundred possible contrivances for tightening them, each and all, at will. If they were attached at B to a piece of tube as are the struts of an umbrella frame, the tube being moveable on the rod at pleasure, and admitting of being fixed in its place by a screw, the tension of the whole might be regulated at pleasure to a nicety. In the case of the flexible bows with the envelope stretched on them, the tube E F (fig. 36), being sufficiently lengthened, would answer the purpose of the rod A B (fig. 37), and the stays, being each attached to one of the bows, would aid the bow-string in keeping the figure in shape. Further, it is probable that if the cords B C, B E, &c., were covered with a cone of canvas resting on them, the resistance of the air to the vessel (unless the curvature of the prow be very sharp, in which case the beak-stays would not be likely to be required at all) would be diminished. The form indeed thus presented—a cone capping a spheroidal figure—is, under certain proportions, Newton's theoretical solid of least resistance.[1] But this point would be determined by the experiments on the resistance of the air, which would be made according to the suggestions given in a former chapter.

In the remaining case, which will probably be the commonest, of gas-vessels in which the envelope is provided with an outer skeleton shell, constructed according to the method described in the last chapter, the means of furnishing it with the requisite outward firmness are simple and obvious. All that is necessary is to cover the framework with a continuous web stretched over it, and strong enough to resist the pressure which it will meet with from the air. The network of bamboo will thus be converted into an outer envelope, as hard and unyielding as can be desired. The opposing pressure of the air acts, of course, directly only on the front part of the gas-vessel; it will, therefore, be only at the fore-quarters and bows that the outer covering will be necessary as a shield. But it will be requisite to invest the whole of the skeleton-shell with a hide or enclosing

[1] See 'Principia,' Lib. II. Prop. iv. Scholium.

membrane, for the purpose of enabling it to receive, especially on the surface of its stern, the static fluid pressure of the air from behind, and to transmit this force forward to the rest of the system. Of course this duty could not be fulfilled at all by the open framework, nor by the flexible envelope without derangement of its form and position. But there are other reasons, as will soon be shown, for making the outer covering continuous and entire.

The next question to be considered is—Of what material must this covering be made? Any kind of strong cloth, silk, canvas, linen, or cotton will fulfil the condition which we are now considering. Thin metallic plate, gutta-percha sheeting, papier-maché or pasteboard, or even thin wood, would answer the purpose, but scarcely any substance would answer so well as woven cloth. The woody fibre of our own flax or hemp will serve us here better, I believe, than any other product we could apply. But before taking leave of this subject, it may be well to enquire what other functions this shell may be made to fulfil. If certain materials would be more suited than others to enhance its utility in other respects, our choice would be fixed upon them. Now such a gas-vessel as we are contemplating is intended to be a permanent structure for out-of-doors work, at least as much so as a ship. It must, therefore, be able to stand all weathers without wearing out very rapidly under regular use. It should therefore be tolerably strong. It must be, of course, as light as is consistent with strength. Though the outer shell need not be of delicate materials, and though there is no reason for guarding the integrity of its texture with any peculiarly jealous tenderness, it will contain within it one of the vital organs of the system, the precious gas-envelope, which will be made with much solicitude of materials that may, perhaps, be very costly, and to which any injury would be productive of the gravest inconvenience, and perhaps danger. This case, therefore, will be able to act the important part of protector and preserver of the envelope. Not only can it be made to shield it from injury by mechanical violence, but to shelter it from the injurious influences of alternate rain, snow, sunshine, and drying wind. No sooner does such a function as this become possible, than it

is also necessary. Indeed, I regard this as one of the most important advantages to be derived from the mode of building air-craft which I propose. The aerial architect and navigator will have, as one of their chief duties, to provide for the careful nursing of the delicate envelope. So long as it is proposed to leave this life-maintaining membrane open to all the destructive influences which are continually threatening its safety when it is free in the air, it is useless to bestow upon its first construction all the care which may so easily be given to it, which is so requisite in any serious attempt to use hydrogen in aerial navigation, and which may all be wasted by the rough handling of a single gale. But when it may be guarded on every side from the inclement touches of wind and weather, as well as from the severer violence of accidental shocks, it becomes imperatively requisite to provide it with the most effectual protection. The material, therefore, of the outer covering must not only be strong enough to resist, or at least to break, the force of all ordinary blows to which the vessel may be liable, but to shelter its contents completely from atmospheric influences. It should, therefore, be waterproof. It should likewise transmit changes of temperature at its surface as slowly as possible to the gas within. It should be made of material that conducts and radiates heat as slowly as possible. This checking of the liability of the gas to sudden contraction and expansion by cold and heat from without, will be a very important function of the outer shell.

Again, I have already alluded [1] to the serious inconvenience which the deposition of large quantities of rain, dew, or snow, upon the surface of the gas-vessel may entail upon the aerial voyager, by loading his vessel, perhaps suddenly, with a great additional weight. Almost the whole of this precipitation of moisture, in the case of our air-craft, will fall upon the outer shell of the gas-vessel, chiefly upon its upper part. The common balloons suffer greatly in this respect by reason of the cords of the net, which not only soak up an immense quantity of water, but, by the meshes resting on the upper part of the envelope, form a vast number of little shallow pools in which the water

[1] See p. 79, above.

may lie. Our gas-vessel will be free from both of these sources of increased weight, for there will be no netting over, and, probably, no absorbent ropes. Its surface will be, of course, smooth, and sloping in every direction. It may be found convenient, hereafter, to build the gas-vessels of a form not circular in section, but narrower horizontally than their vertical depth, for the purpose of enabling the water to run off rapidly. It may be useful, too, to provide the gas-vessel with projecting eaves all round its greatest horizontal outline. These would throw the water off, and prevent any more from investing the lower surface of the vessel than might be condensed upon it from the atmosphere. In case of a heavy fall of rain from above upon the top of the vessel, this would diminish the load of water lying upon its surface at any one time by nearly one-half. If this eave were converted into a gutter, connected with a pipe running down to the boat, the water might be collected and kept, if required, as may sometimes be the case, for ballast, or for the use of the steam-engine, or could be allowed to run off if the system were already too much loaded. But, however this may be, it is important that the outer surface of the covering be of such nature that the wet should have the least possible tendency to adhere to it. The object to be sought will be to give to the surface such a quality as that which is possessed by the feathers of living water-birds. A few experiments would soon find for us an excellent material for this purpose. Few substances are more repellent of water than the linseed-oil gum.[1]

If a piece of paper (however bibulous of water in its ordinary state) varnished on both sides with linseed-oil gum, the coating having been allowed to set completely, be dipped in water, it will be found that the liquid will scarcely adhere to it at all, but will run off almost entirely on inclining the surface. The fatty oils seem to confer this property in an inferior degree, for they do not engage all the downy fibres of the piles which all textures,

[1] The disinclination to be wetted by water is of course a different property from that of being waterproof: the first depends upon a molecular property of the surface of a body, the second on the closeness of its texture; the latter may of course be much aided by the former condition.

woven or papery, present more or less, in a perfectly smooth polished surface, as does the varnish of the setting oil. It is very likely that some means might be found of enhancing the wet-repelling quality of this material to a very high degree. It is a well-known fact that the surface affections of different substances, as respects different liquids, vary very greatly. There are many liquids, for instance, which will not moisten glass. Polished metals are readily moistened by fat oils, but reject water; and this they do the more energetically the hotter they are. The laws of these phenomena of surface adhesion have not been much studied, nor am I aware of any process or practice in the arts, except anastatic printing, and the bottling of mercury, in which it has been found requisite to make use of these relations of liquids and solids. It is probable that no one has ever found a motive for searching for the best repeller of water, as there was no application demanding it. But aerial navigation here presents a purpose, which makes it incumbent on us to find speedily the best means of imitating the ducks in the treatment of their feathers.

This protection of the envelope does not, perhaps, absolutely require that the water shell of membrane should be continued over the whole framework on every side. It would, however, give it far more complete security if it were so arranged. It is scarcely necessary to remark, that the strength of the covering will be of great service to the envelope, in assisting it to sustain the upward pressure of the gas at the top of the vessel. For this purpose it will be better that the covering should be double at the whole of the upper part of the vessel. Since the framework is to be made of ribs and ties crossing each other in various directions, and presenting therefore a number of uneven ridges instead of a smooth surface for the envelope to rest against within, this arrangement would endanger the integrity of the envelope, which would be strained tight over each of the ribs by the pressure of the gas, without any support to the part between them. The upper part of the skeleton shell ought therefore to be lined with strong cloth fastened to each of the ribs, and be stretched, so as to form an even surface. The envelope would rest securely against this lining, which should be smooth or soft

on its inner side, so as not to chafe the valuable texture within it. It would be further supported by the diagonal ties between the ribs. The outer casing would be requisite to throw off the rain-water, which, if it were absent, would lodge against the ribs upon the inner lining.

Very important service would be rendered by these coverings, if made gasproof, by helping to preserve the balance of buoyancy. For, of course, any gas that leaked out of the envelope would be retained by them, and would have to work its way through their pores before it could escape. Meanwhile, of course, the hydrogen within the envelope would have much less tendency to diffuse into an atmosphere of mixed air and hydrogen than into one of pure air. But there is another function which the outer covering will fulfil, if it form a complete casing to the envelope, that of freeing the system from liability to a derangement which I have already pointed out as necessary to be prevented.[1] This is the alteration of the balance of level when the envelope is only partially full, through the gas rushing by its momentum to one end of the vessel, on occasion of any sudden change in the speed of the air-craft's motion. The manner in which the outer casing is to effect this may not be at once obvious to the reader; I may therefore explain it in a few words. The gas vessel must be supposed to be like a common balloon, or eggoon, flexible, without casing, and only partially charged with gas. The cause of this gathering of the gas towards one end will be, that while such a gas-vessel is moving in any given direction, the gas within the envelope is moving with it, and has momentum in proportion to its mass. Now the air on the outside of the envelope has no such momentum of motion, but is at rest, or nearly so, as respects the onward course of the vessel. If, then, the system be suddenly checked or accelerated when in motion, the new velocity is simultaneously communicated to the whole of the rigid gas-vessel, but only by degrees to its contents, every particle of which continues, at first, to progress with the original rate of motion. The gas therefore tends to gather itself together as close as possible to that end of the vessel which it is either

[1] See p. 59.

overtaking, or being overtaken by; and there is nothing to prevent this from ensuing, except the resistance which the air at rest opposes to it, and the unwillingness of the envelope to bend. Now the matter is at once compromised with the air outside by that fluid being disturbed to a certain extent, to which and no further it can rob the gas of motion. The more inflexible the envelope, the more it approaches to the condition of a vessel completely full, for its walls must always be in contact with its contents over their whole surface, however small the proportion may be which those contents bear to the capacity of the vessel. If, however, the vessel be completely full and distended, this packing of the gas towards one extremity cannot take place, except in such a trivial degree as may be permitted by the elasticity of the gas, which will condense itself slightly towards the end in question by one part pressing upon another, as the rear ranks of a moving crowd may crush the front row against a wall that suddenly stops it. And even this can scarcely take place to any perceptible extent, if the gas-vessel be inflexible as well as full; for in this case the gas cannot condense itself in one part without being rarefied at the other end—a mode of disturbance which will rectify itself instantly.

Let, however, our pliable half-full envelope be enclosed within an outer rigid casing, which, besides the gas, contains a quantity of air, not like that on the outside of a free and unprotected envelope at rest, but moving with the gas, and under exactly the same conditions. The case is now altogether different. The gas has now no greater momentum, and therefore no more tendency to collect at either end, than has the air against which it presses, and which now is imprisoned with it. The air at the bottom, and the gas at top, tend equally (or rather in the proportion of their masses) to gather at one end, and so mutually oppose each other in their endeavours to get there. The conditions are, in fact, exactly the same as those of a rigid vessel completely full of gas; the only disturbance that can ensue is one of condensation, not of displacement.[1] It will not be necessary for

[1] It is true that if the mass of air within the vessel, below the envelope, were considerable, it might give rise to a certain gathering of the hydrogen towards the end opposite to that which communicates the change of motion

securing this service, that the outer casing should be airtight, still less that there should be any pressure of its contents from within. All that will be requisite is that the free communication of the common air within the vessel with that without should be so far cut off that the enclosed atmosphere should share the motion of the system, and travel with it. This would be, perhaps, best managed by having on the lower side of the vessel two valves lightly loaded, one opening inwards, the other outwards; these would allow the air to enter or escape, as the contents of the vessel expand or contract in obedience to the changes of temperature and pressure. The latter function of escape would be served by the two valves suggested in the last note. If they were adopted, a single valve in the middle of the belly opening inwards would provide for the ingress of air.

The requisites, then, of the covering, which is to be stretched over the skeleton-shell, may be thus summed up. It must be in texture light, strong, waterproof, and gasproof; of a water-repelling surface; of structure continuous over the whole outside of the vessel, except at such apertures as may be necessary for the service of the envelope, and for the restricted passage of atmospheric air, to and from the interior of the vessel. I can imagine no substance that would fulfil these conditions more perfectly than linen or hempen web, well varnished with the gum of their own oil.

We have now completed the design of the body of the compound gas-vessel, which may be briefly thus described:—Its outer

to the contents, as it would displace the lighter gas by virtue of the greater momentum of the denser fluid. But this result, the difference of two similar actions, would rarely amount to anything important, as the hydrogen would almost always be present in greater bulk than the air within the vessel; and this effect might be neutralised to the most perfect nicety by having on the lower part of the bows ('*bovs*') and of the stern of the gas-vessel, a valve which should open outwards, and which should be kept closed by a spring, of which the strength should be increased as the bulk of gas within the envelope increases, and diminished as the gas dilates. This apparatus, which might easily be made self-adjusting, would allow some of the air to escape, if its pressure towards one end should preponderate too much over that of the hydrogen. But this perhaps is a needless refinement of contrivance.

coat is the covering of which the qualities have just been specified. Within this is the frame of longitudinal bamboos, which, in turn, are supported within by the circular rings, which are strongest at the lower side. These two sets of frame-ribs are laced together by diagonal ties. Within them, over the upper half of the inner surface of the vessel, is stretched a lining of strong cloth, varnished perhaps with oil gum on the outside, and with a soft face within. Next to this comes the envelope, with its bowstring cord running through its axis from end to end, and tied to the extreme ends of the beak and tail of the outer vessel. The envelope thus always enclosed, and extended in its sound weather-worthy shell, will be far more durable than any balloon, which is continually being folded up and thrown into creases. The top of the envelope when charged will be pressed firmly against the roof of the case, while its lower side will be floating in the midst, pressed up by the air against the lowest surface of the body of light gas. There will be some appendages to the envelope, of which I shall have to speak hereafter, besides those which have been already mentioned.[1] The introduction of these will necessitate some trifling modifications in the construction of the outer shell of the vessel, such as the cutting of holes to allow tubes to pass; but these will be so simple and obvious that it is scarcely worth while to mention them.

Before proceeding to fill our vessel with gas, I must remind the reader who, perhaps, is appalled by the great weight of my proposed gas-vessel, that iron ships are heavy structures, and that, nevertheless, they float. I must also refer him to some remarks upon this matter in the last chapter.[2] I do not think that I need be accused of making any very exorbitant demands on the reader's imagination, or on the levity of hydrogen, by advocating an ark of bamboo and varnished linen, when it is remembered that some aerial schemers seriously discuss the building of gas-vessels that shall lift a man-of-war with a hundred and twenty guns, and all its crew and armament on board.[3] Some persons, however, are still alarmed by the great size which som of these vessels must have. The answer to this is that the

[1] See p. 250, above. [2] See p. 253, above.
[3] See Monge, 'Études,' p. 158.

relative size increases less and less rapidly, as the actual size and burden is greater. So that the larger the vessel, the less really, and very much less, is its monstrosity. Besides, reader, there is plenty of room, between the earth and the moon, for all the air-craft we shall ever launch in this world, however huge their bulk. I am particularly anxious, too, to show ground for believing, that working-air craft may be made of reasonably small dimensions, and if I did not think I could first accomplish this, I should not have ventured to sketch a plan for the building of more colossal vessels for ulterior use.

CHAPTER VII.

CONDITION 5.—THE ENVELOPE MUST BE CHARGED WITH THE LIGHTEST GAS.

THE body of our gas-vessel may now be considered as finished, so far as concerns its outward organism. Its contents, however, are as much a part of its structure as the feather stuffing is a part of a pillow. The gas, then, with which the envelope is to be charged, and which it is now ready to receive, comes, properly, next under review.

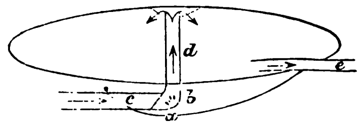
The general requisite to be fulfilled is, that the gas-vessel must be charged with the lightest possible gas. But it is also necessary that this source of buoyant power should be cheap; and hydrogen is so far lighter than any other known gas, that our choice may be fixed on this substance for our present purpose. The end, then, that is chiefly to be sought is to find a means of producing hydrogen in large quantities at a low price.

However, before proceeding to discuss this point, the possibility of using other gases as the agents of floatage may be briefly considered. I have shown in my first part, in the chapter that corresponds to the present, that the buoyancy of heated air is not likely to be extensively useful for purposes of rapid locomotion through the air.[1] However, for air-craft of heavy burden, and not intended for very rapid flight, it is probable that heated air may serve as an agent of floatage. Vessels intended to be lifted by the rarefaction of the air need not be furnished with an interior envelope, like those of the gas-vessels for containing hydrogen. They would be built of canvas, rendered uninflammable by alum or silicate of potash, or of metal plate, and would

[1] See p. 118, note.

be kept in shape by a skeleton framework of metal tubes, constructed on the principles laid down in a former chapter. If the shell were made double—the inner coat performing the office of retaining the hot air, the outer of repelling wet—with the skeleton frame, and a thin layer of air between them, the heat would be considerably economised by the prevention of its transference to the air without. The air-vessels being of great length, might be supplied with heat by as many furnaces as might be desired. A special fire boat would be arranged for this purpose along the belly of the vessel. The mouths of the furnaces would be directed forwards, so as to receive a current of air upon their fuel, light chimneys of thin metal plate would run from the furnaces to the top of the air-vessel within, and tubes opening towards the stern from its bottom, would discharge only the cooled air which has done its work. Such an arrangement is

Fig. 38.



represented in the diagram fig. 38, in which *a* marks the furnace, *b* the stoker's doors, *c* the draught mouth, *d* the chimney, *e* the discharge pipe. By this means a regular draught would constantly set through the float, carrying in hot air and floating power, and throwing out air exhausted of its buoyancy. The rate of this draught would be regulated by a damper in the mouth-piece of the furnace, which might easily be made self-governing by poising it about its horizontal diameter, and connecting it by a lever with a light plane or sail stretched horizontally, which would receive the pressure of the air on its upper or under surface, according as the craft might rise or fall. So that, if the heat became too feeble, the vessel, sinking, would cause a pressure on the lower surface of the governor plane, which, by its lever, would open the damper valve, and allow the fire to increase. The best fuel for this purpose, and for all services in Aerial Navigation, are the liquid hydrocarbons.[1] But with a well-constructed furnace and

[1] See Chap. XIV.

gas-vessel, coke no doubt would answer the purpose perfectly. If the fire should require a greater supply of air than could be obtained by its regular draught through the flues just described, the heat might be increased by a blower driven by the propelling mechanism, or by a source of power specially devoted to the service of the gas-vessel. I conceive that by a well-adjusted apparatus, fitted together on the plan here sketched, hot air might be made very useful in affording floatage for aerial vessels. There would not be the least danger attending the use of fire under these circumstances, certainly not more than there is in burning fuel in our dwelling rooms. The accidents which have occurred with balloons charged with hot air, have arisen entirely from the absurdly ill-contrived apparatus in which the fire has been placed. The advantages attending this mode of obtaining the required buoyancy are in some respects very great. The envelope need not be made of such expensive materials as must the gas bag for hydrogen. Its contents cannot be costly anywhere; the vessel may be charged in a few minutes; and may be made to rise or fall in the air quickly, without any additional appliances. Finally, it must be remembered that—given the diameter of our vessel, and its appropriate length, for a given duty when filled with hydrogen—we have only to add to its length, to render it quite as capable of supporting the same burden, and of maintaining the same speed with the same propelling power, when charged with hot air, as when inflated with hydrogen. However, the hot air vessels may be contented to enlarge their diameters, and to travel at lower velocities, carrying cargoes of dead goods, while hydrogen dashes along with its burden of living men.

Among the gases which might be used for the purposes of buoyancy is one which, so far as I am aware, has never been proposed for it; but which, though it might be impracticable to apply it as the chief agent, has some properties which might enable it to do some service. This is ammonia. The specific gravity of this gas is ·597, that of air being 1. 100 cubic inches of air weigh 30·829 grains, and 100 cubic inches of ammoniacal gas 18·405; so that 100 cubic inches of ammonia have a lifting power of $30{\cdot}8-18{\cdot}4=12{\cdot}4$ grains. This is not expressive of

any great buoyancy. And the strong alkaline properties which ammonia acquires when it comes in contact with moisture might make it a difficult substance to manage in the gas-vessels. If, however, any flexible envelope stuff should be found which would not be injured by it (such as vulcanised caoutchouc), it has some properties which might make it useful, not perhaps as a material for filling the gas-vessels altogether, but supplementally for the purposes of adjustment. It admits of being readily liquefied: when subjected to a pressure of 6·5 atmospheres at a temperature of 10° centigrade (50° Fahr.), or, under the ordinary pressure of the air, at −40° C. (−40° Fahr.), it assumes the liquid state. So that, with this gas, the project before mentioned,[1] of carrying in the air-craft a reservoir of liquid gas, for the purpose of adding at will to the buoyancy of the system, is actually possible; and it is the only gas that could serve as an agent of buoyancy, that has this property of being liquefied, and therefore so enormously reduced in bulk as to become in this manner a portable source of lifting power. But it has another property, that of being energetically condensed, without the application of mechanical power, into a state from which it may be recovered, without any elaborate process of chemical decomposition. Water and charcoal absorb ammonia greedily, taking up respectively 500, and about 90, times their volume of the gas. The absorption of the gas by water takes place with vast rapidity, as soon as the surfaces of the two substances are in contact. And from either water or carbon the gas may be obtained again, by the simple aid of heat. This property might be of service for the purpose, hereafter to be considered, of altering the buoyancy of the craft upon occasion.

But to return to hydrogen. In a former page I mentioned some processes, which had been adopted and proposed, for the purpose of making hydrogen at a cheap rate. One of these, the method of passing steam over iron at a red heat, has been already proved to be very effective, and by no means expensive. But to render it commercially successful, there should be no unnecessary waste of material. The same iron must be used over

[1] See p. 72, above.

and over again, being reduced from the state of oxidation in which it is left by the steam. This reduction may be effected by mixing coal, coke, or charcoal with the residual oxide, and by subjecting the mixture to a high temperature. In this operation, the carbon robs the metal of oxygen, and is converted into carbonic oxide, or carbonic acid, according to the proportion in which the materials are mixed. There seems to be some doubt as to the state of oxidation in which iron is left by the action of steam at a red heat. The value of this method would depend upon this—whether it were necessary to subject the iron to a temperature that would fuse it, for the purpose of effecting the reduction. If this were the case, and the metal were only obtained again as a liquid mass, the process might become expensive. However, the oxide that is most likely to be formed, and probably any other of the oxides, in the condition in which the product would be presented, would be reduced to the metallic state, by being simply raised to a white heat in contact with carbon.[1] All that would be necessary for obtaining the iron again, in a form fit for the production of hydrogen, would be to mix it with an excess of carbon in a fine state of division, and to heat it in a closed vessel, to the lowest point at which its reduction can be ensured, so as to avoid fusing the mass. The contents of the retort or crucible, being cooled before exposure to the air, would be then thrown into a vessel of water, by means of which the iron would be separated from the lighter particles of carbon, and would be again ready for the steam retort. But there is another mode of reducing the iron, which would, perhaps, yield a better result. Carbonic oxide, as well as hydrogen, reduces the oxides of iron to the metallic state, at a temperature as low as a red heat. This property affords a most excellent means of making the same iron alternately take oxygen from water, and give it up again, without being ever removed from the retort in which it is subjected to heat. This vessel, of course, must be made of fire-clay, to avoid the destruction of its substance, which, if it is made of iron, must ensue from the very same process, which is required to go on within it. There should

[1] Gmelin, 'Handbook of Chemistry,' trans. by Watts, v. 5, pp. 186, 191.

be two rows of retorts and furnaces. One of the sets of retorts should be charged with iron turnings; these—in an aeronautic port, where large quantities of hydrogen would be continually required, and the process would be always going on—might be kept always red-hot, without intermission. The other set would be charged with coke or charcoal, and would only require to be heated in alternate periods. The steam-boilers would be always at work without relaxation The process would be the following:—The steam being up, and the iron-charged retorts red-hot, the steam is to be turned on over the iron, oxide of iron is formed in the retorts, and hydrogen passes off; this goes on till no more gas is obtained. Meantime the carbon-charged retorts have been heated red-hot, the steam is now to be turned off from its direct route to the iron retorts, and led round over the carbon, and thence to the iron. The steam passing through the first retorts is converted, with the carbon, into carbonic oxide and hydrogen, and the mixed gases, passing then over the iron, rob it of its oxygen, and form carbonic acid and water. This goes on till inflammable gases are found coming from the second retorts, and the carbonic acid ceases; the steam is then to be turned off the carbon, and sent direct to the iron retorts, which, now containing metallic iron, again yield hydrogen, and so on. Nothing can be simpler than these operations; though there can be no doubt that there would be many minutiæ to be attended to, which can only be learned by actual experiment. It would, of course, be necessary to take care that the carbon-retorts were constantly supplied with an excess of charcoal, to prevent the formation of carbonic acid, which would retard the process, by imparting half of its oxygen to the iron, and so far neutralising the effect of the hydrogen and carbonic oxide.[1]

There is another method of procuring hydrogen, which seems never to have been proposed for practical application, though the

[1] See p. 115, note. It is likely that this iron, by its repeated oxidation, reduction, and high heating, would become extremely pure, and might be valuable for many purposes in which a fine metal is required. There can be no doubt that this steam-coke, or steam-coal process, might be used with great advantage in practical metallurgy, in reducing many of the metals from their ores.

fact of its possibility has long been known to chemists. Everybody knows that zinc is the most electro-positive of the common, easily-reduced metals, and that it is therefore the favourite agent for decomposing water and salts in the voltaic battery. But the utility of this metal, for the formation of hydrogen by the hot method, seems to have escaped notice. Now there are several advantages which this metal has over iron, as an agent for the decomposition of steam on the large scale. It decomposes the vapour of water at a lower temperature than does iron, even when finely divided, at a temperature but little above that of boiling water, and of course more readily at higher temperatures. It melts at a temperature between 400° and 500° Cent., and boils at a white heat. These properties make it a most easily manageable metal for our purposes. The steam may be decomposed, either by passing it over the surface of the melted metal, or by bringing the vapour of water into contact with the vapour of zinc. In either case, the current of gas will carry away with it from the surface of the metal the oxide that is formed, and so leave the surface continually fresh and free. In the latter case, for which a higher temperature would be required, no doubt oxide of zinc would be obtained, in the same form in which it is procured by mixing the zinc vapours with air—the white powder, so valuable as a non-poisonous base for paint. This process, of course, would be conducted in a retort, into the neck of which the nozzle of a steam-pipe enters, and which opens into a large chamber, in which the powdery oxide would be deposited. In whatever form the oxide was obtained, whether saleable or not, it would have a constant value with the hydrogen-maker. For he would only have to reduce the oxide, to obtain his metal again ready for use. The oxide of zinc is not quite so readily decomposed by carbonic oxide, or by hydrogen, as are the oxides of iron, but to carbon it readily yields its oxygen, even at a red heat, forming carbonic oxide, or carbonic acid, according as much or little charcoal is mixed with the oxide. As the object would not be to purify the zinc, but merely to obtain it in the metallic form, it would not be necessary to heat the crucibles to a white heat, and to distil the metal, which is the universal practice in the metallurgic reduction of zinc ores. For since the reduction

takes place at a lower temperature, the metal will melt and run to the bottom of the vessel; and will be ready again for subjection to the treatment with steam.

These processes for obtaining hydrogen resolve themselves in fact into an artifice for converting charcoal into hydrogen. The metal is merely a constant part of the apparatus, an instrument of the change. Each equivalent of hydrogen in the water is replaced by one of carbon, the hydrogen being set free instead of the former cheaper and more vulgar element, which the oxygen has to take to itself in place of the subtle gas. The only other expense of the process is the fuel necessary for producing, and maintaining, the heat necessary for the operation. In each of these methods, instead of passing the steam from a separate boiler over the metals or carbon, it may be more economical to allow water to trickle directly into the heated retorts, so that the steam should be formed as it is required. The process would be exactly the same in either case.

However, it may be sometimes desirable to produce the hydrogen, without the immediate use of fire. The old process, of treating iron or zinc scraps with dilute sulphuric acid, is, of course, the means that offers itself at once as the cheapest for this purpose. It should be conducted in large vessels of copper, or, as suggested by M. Monge,[1] of lead, instead of, as is usually practised, in wooden casks. If a receptacle formed of one of thèse metals, which are electro-negative to zinc or iron, were used to hold the acid, and either of the latter metals, during their mutual action, the water would be decomposed by voltaic polarisation, and the gas would be given off more rapidly, as it would arise from the surface of the passive metal, not from that which would be undergoing solution; and thus the contact of the acid with the zinc, or iron, would not be impeded by the bubbles. The great objection to the use of the acid process has been, that large quantities of metal and acid were used up, and that there was no market for the resulting sulphates. But there need be no such loss, at least not a loss of by any means the whole of the acid. It is well known that common green vitriol,

[1] 'Études,' p. 19.

(sulphate of iron,) is used in Germany for the preparation of the fuming acid liquor called Nordhausen acid. If the salt which is obtained in the manufacture of hydrogen from iron and sulphuric acid, be crystallised, and distilled at once at a red heat, the whole of the teroxide of sulphur is driven off, but half of it is decomposed into binoxide of sulphur and oxygen, which latter unites with the oxide of iron, forming sesquioxide.[1] If, however, the dried salt be first roasted at a lower temperature, with access of air, the attachment of the metal for oxygen is satisfied at the expense of the atmosphere, and the bisulphide of the sesquioxide of iron is formed. If this salt is now distilled, it yields up, without loss or decomposition, the whole of its teroxide of sulphur in the required form. This is the process which is adopted on the Continent; the common sulphate of iron is first roasted, and then distilled—the same furnace serving the two purposes for different portions at the same time.[2] The red-brown sesquioxide of iron, called in the state in which it remains in the retorts, 'colcothan,' is useful as a pigment, and for polishing glass and other substances. It may, of course, if there is no market for it for this purpose, be reduced to the state of metal by the methods before mentioned. There can be no reason that this process, which has been in use for centuries in Germany, should not be applied here, in a case where the product would be wanted for direct consumption, and would be obtained for the mere cost of the fuel. Iron would probably be used in preference to zinc, for producing hydrogen by the acid process, on account of its cheapness, and for the reason, that the zinc-sulphate does not yield up the whole of its sulphur in the state of teroxide on distillation, a portion of it being given off as binoxide, with an equivalent of free oxygen. It is, however, extremely probable, that by distilling it in an atmosphere of steam, which would encourage the formation of sulphuric acid by hydration of the teroxide of sulphur, this

[1] Teroxide and binoxide of sulphur are commonly called anhydrous sulphuric acid and sulphurous acid; but neither of them are acids at all, they form acids when in combination with water. The liquid obtained by distilling the sulphates becomes sulphuric acid, when water is added to it.

[2] See Knapp's 'Chemical Technology,' trans. by Ronalds and Richardson, vol. i., p. 253, for an account of the process, and of the apparatus used.

loss might be prevented. Zinc-oxide remains behind in the retort, which may be reduced with charcoal, and used again. The oxide of zinc may also be obtained from the solution of the sulphate, by precipitating it with ammonia, potash, or soda, taking care not to add excess of the alkali, lest the oxide be redissolved. By adding carbonate of potash, or of soda, to the solution, the zinc may be obtained as carbonate of the oxide, from which the metal may be recovered as readily as from the oxide. The alkaline sulphates obtained from this treatment, in solution, have a commercial value. The oxide of zinc may also be precipitated by lime-water, but the difficultly soluble sulphate of lime, being mixed with the oxide of zinc, renders the process of reduction of the metal more difficult. If it be desired to recover the zinc with the sacrifice of the acid, the sulphate of zinc having been dried by evaporation, and mixed with charcoal, and the mixture gradually heated, the metal may be obtained directly by a single process, the sulphur and charcoal going over as gaseous compounds with the oxygen of the salt. If, however, the heat be too suddenly raised, the sulphur remains behind with the metal as a sulphide.

These methods are quite sufficient to yield hydrogen as cheaply as can be desired. In the best of them the metal, iron or zinc, is to be considered as a part of the apparatus, in which there will be no expenditure except that of the first outlay of capital. There will be no waste of anything but the carbon. Of carbon in some form or other, coke or coal, there will be consumed in the operation, supposing the steam-zinc process be adopted, one portion to generate the steam, one portion to keep the metal hot for the decomposition of the steam, another (a chemical equivalent of the hydrogen) to decompose the oxide of zinc, another to keep up the heat of the crucible during the reduction. And, as I shall have occasion to show hereafter, carbon, when converted into carbonic acid, need not be considered as lost; it has still important services to render before it need be wasted.

When we have found the means of making the voltaic current do its work cheaply, as a source of mechanical power, we may find that the hydrogen, which may be formed as an incidental

product, will be useful for the purposes of the aeronaut. Whether conversely mechanical power can be made, by the aid of magneto-voltaic arrangements, to decompose water at a profitable rate of cheapness, must be determined by careful experiments. Future improvements may effect this, although the sanguine assertions from America with which the public have lately been amused, will be found truthless. Since Mr. Paine, however, another gentleman, M. Nollet, of Brussels, claims to have discovered means of decomposing water, with great energy and rapidity, by means of the magneto-voltaic current, and of supplying 'hydrogen in any quantity, either for illuminating or for motive purposes.'[1] We shall see.

I shall hereafter have to mention another means of obtaining hydrogen by chemical action which, though I shall not recommend it for the purpose of procuring the entire charge of gas for the air-craft, will be very serviceable for an object for which I shall have subsequently to provide.

The gas-vessel having received its charge of buoyant matter, is now ready to lift its burden. The next step, then, in the construction of our craft, is that of slinging to the float the vessels which are to carry its crew and cargo. This important point, on which the capabilities of the system of being really useful depend, as closely as upon any other of our conditions, forms the subject for our next chapter.

[1] 'Mech. Mag.' vol. liv. pp. 362, 410.

CHAPTER VIII.

CONDITION 6.—THE VESSELS MUST BE ABLE TO KEEP A LEVEL POSITION, WHEN PROPELLED THROUGH THE AIR.

'GIVE a knave,' they say, 'rope enough, and he will certainly hang himself.' The would-be aeronauts, then, are by no means knaves, for they have had endless rope for seventy years, and they have not yet hung themselves—to any purpose. It is a most singular fact, as I have already remarked,[1] that none of the projectors of aerial navigation have ever given a complete design for an air-craft, in which the boat containing the propelling agents was to be hung from the gas-vessel in such a manner that it could effectually do the work assigned to it. The wonder is enhanced by the fact, that the method of suspension by which this result may be best ensured is extremely simple, as I shall presently show.

However, before coming to this point, we must consider what differences of arrangement the air-craft admits of, with respect to the application of the force, and to another matter which is very closely connected with this, the distribution of the burden. Now the idea of the air-craft is that of a true organic structure.[2] Like the perfect animal body, it consists of a mechanism embodying three primary functions, two of which, specially when the system is in due balance, present, as it were, a chief polarity, being a pair of forces in equilibrium, and acting in opposite directions.[3]

[1] See pp. 41–54, above. [2] See p. 191, above.

[3] See note, p. 24, above. The polarity in the case of the air-craft is not a true one, just because our structure is not a perfect animated system, like the universe, a magnet, or a cheese-mite. The antagonism of the lightness and heaviness of the gas and its burden represents, not is, a polar

The three fundamental qualities are lightness, speed, heaviness; and have their places respectively in the three chief parts or organs of the system—the float, the propeller, the burden. Further, like every organic type, the air-craft admits of varying degrees of development, in which, according to the advancement and dignity of the kind, the distinction of the functions will be more marked, by the concentration of their instruments into separate and appropriate organs.

The lowest type of air-craft—like the simplest animals, the acrita, which have no distinct organs, but are all leg, all lungs, all stomach, and, for aught we know, all brain, seeing ever into the life of things, with the sleepless eye of rapt contemplation—is the simple balloon. Its first development is, like the polarisation of the animal ovum into germ-yelk and germ-cell,[1] the separation

relation. If we could organise our structure perfectly, this condition would obtain, the forces would be mutually dependent, and would keep each other in balance. I shall endeavour to show hereafter how this may be done partially, to a slight extent.

[1] Owen, 'Parthenogenesis' (1849, p. 4), which might well be called 'The development of animal life by polarisation,' for it is a history of the successive establishment of a series of polarities, by which all animals are built up, like all the rest of nature, as upon a scaffold, in a chain of regular separations and concentrations, two and two, of each of which the magnet is the type. I must, however, beg the reader to understand that I do not accuse Professor Owen of hinting or even meaning this. He once uses the word 'pole' in illustration (p. 8), but apparently without any serious intention of pointing an analogy. Nevertheless, designedly or not, he gives in almost every page an exemplification of the great law of polarity, the law of universal structure, which is thus announced in general but precise terms by the ancient seer, 'In the beginning God created the heaven and the earth,' 'And God divided the light from the darkness,' 'And the evening and the morning were the first day,' 'And God divided the waters which were under the firmament, from the waters which were above the firmament,' 'And God said, Let the waters under the heaven be gathered together into one place, and let the dry land appear,' 'And God called the dry land Earth,' 'And God said, Let the Earth bring forth grass, the herb yielding seed after his kind,' 'And let the waters bring forth abundantly the moving creature that hath life, and fowl that may fly above the earth in the open firmament of heaven,' 'And God made two great lights—the greater light to rule the day, and the lesser light to rule the night,' 'So God created man in his own image, in the image of God created he him;

of the system into the float and the car. It is now such a creature as one of the radiate animals, in which certain organs have begun to assume special functions, with a feeble attempt at voluntary locomotion, with a considerable aptitude for the making a livelihood, but with no useful work to show in return for it. In its highest stage of development, of course, the air-craft will, following out the law of concentration[1] and of true simplicity in complexity, find its three primary functions executed by three distinct and

male and female created he them.' This is plain enough, the last verse quoted especially. I hope I shall offend neither author nor reader of either of these books by saying that I think the first chapter of the 'Parthenogenesis' of Mr. Owen, must be the finest comment yet written on the first chapter of the Genesis of Moses. For the magnificent beauty of the latter is dimmed and lost by considering it merely as the history of a set of events, and not as the account of the order or law of all Creation. Verily, M. D'Olivet, if he did not learn, as he says he did, from Genesis, how to cure the deaf and dumb by Human Magnetism, has some grounds for asserting that he found in its early chapters the key to all the sciences. (See 'Notions sur le sens de l'ouie' Par Fabre D'Olivet, ed. 1, Paris, 1811, 8vo. p. 12, and 2nd ed. Montpellier, 1819; also by the same author, 'La Langue Hébraique restituée,' Paris, 1825, 4to., seconde partie, p. 6.)

[1] 'True complexity,' says the great philosopher to whom I have just referred, 'is not shown in the number, but in the variety and co-ordination of parts.' (Owen, 'The Nature of Limbs,' 1849, p. 36.) 'The vegetative repetition of parts' seems to be as truly characteristic of a low state of development as is the execution of several functions by a single organ. The idea of the aerial vessel has passed through this phase of growth; instances of this are the proposal by the elder Monge (grandfather of the author of the 'Études sur l'Aérostation') to unite a long chain of balloons, like the vertebræ of a snake, a low type creature, into a necklace, and to make them propel each other. I cannot find any account of this, so I cannot refer the reader to it. Other instances of these vegetative repetitions, without pronounced function, are Dr. M'Sweeny's projects (M'Sweeny, 'Aer. Nav.' 2nd edit. pp. 57, 58 60); M. Petin's scheme, of four balloons fixed in a frame ('L'Illustration,' September 6, 1850); and, though far higher in the scale, Mr. Sadd's twin gas-vessel. (See p. 46, above.) By the way, in reference to the correlative law of concentration of function (which in zoogony is the analogue of condensation in cosmogony), it is manifest from the imperfect though far advanced, fulfilment of this law, even in the human organism, that man is at present either in an undeveloped or in a fallen condition. There are perhaps physiological evidences that in bodily state he has actually taken a step backward. But I am getting off my subject.

separate parts of the mechanism, just as, in the higher vertebrate animals, the nervous system is gathered into three distinct centres, which separately perform their functions, without, in the healthy state, any confusion of their special spheres of consciousness.

There are, then, three possible classes of air-craft. Firstly, that in which there is no separation of parts, but one vessel. Secondly, that in which a bipolar splitting into two parts has taken place, there being a gas-vessel, and a body hung to it. Thirdly, that which I believe to be the highest and most perfect form, having the widest sphere of utility, that, namely, in which there will be three distinct vessels, one for gas, one for propelling power, one for burden; in short, a perfect insect,[1] the true aerial type—with, if you please, head, chest, and trunk. I shall consider these three classes separately. Each, of course, that it may be duly propelled, will require a peculiar arrangement—in the two latter cases, a peculiar mode of suspension of the other parts to the float.

Before proceeding to enter into the details of the anatomy of each of these classes, we must first determine the general requisites, as respects the articulation of their limbs. When we have a general expression for the condition according to which the propelling force must be applied, we shall be able to adapt the rule at once to each form of organism, as it comes in turn under review. The non-fulfilment of this condition is one of the chief reasons, as I have already shown,[2] of the inadequacy to their end of most of the modes of aerial navigation hitherto proposed. In the chapter referred to, I endeavoured to point out how the force must not be applied; I have now to consider how this part of the construction must be arranged.

The general end to be attained is this—which applies equally

[1] It is worth remembering that the same law holds good among the highest class of animals taken above—the mammals. The lowest types in different circles are of simple inarticulate form, the whales, the seals; the highest of all, yourself, reader, are the most truly 'insect,' that is, cut into distinct parts, each outwardly embodying one of your three lives, as, inwardly, they are centred in your three nervous systems. (See note, p. 20, above.)

[2] See Chap. III. above.

to all the species of every class of air-craft—that the resultant of the propelling forces on the gas-vessel shall ultimately coincide, in direction, with the axis of resistance. By this latter term, I mean the direction of the resultant of the resistance of the air to the forward motion of the vessel. The float being symmetrical in every direction about its longer axis, which is parallel to the direction of motion, the axis of resistance is the same as that of the vessel.

Now we may consider that two active forces are exerted upon the float when in motion, namely, the weight acting vertically, and the propelling force horizontally. These are kept in equilibrium respectively, when the motion is uniform, by the buoyancy of the gas, and by the passive resistance of the air to the bows of the gas-vessel. If the weight of the system be not so placed that its resultant passes through the centre of buoyancy of the gas, it will tend to twist the float round, until this is attained. It is necessary therefore, to the end that this derangement may be prevented, that the burden shall be so disposed that the resultant of its weight shall pass through this point. When the system is at rest this, of course, is the case, if the centre of gravity of the load lies vertically beneath the centre of buoyancy of the float. When the craft is in motion, another position for it may be necessary, to secure the maintenance of the gas-vessel in a true horizontal level. For, again, the propelling force, if not applied directly in the line of the axis of resistance, will have a tendency to twist the system round a horizontal axis, at right angles to the former.[1] And, as will presently appear, if both of these forces

[1] For if not, a couple will be formed, consisting of the resistance of the air to the gas-vessel acting at one end of an arm, and the propulsion acting at the other in the opposite direction.

In actual truth, another couple will be formed in most cases, if the propelling power be made to act exactly in the line of the axis of resistance,—a couple, namely, formed by the inertia of the system acting through the centre of gravity, on the one hand, and by the propulsion on the other. I have omitted to notice this in the following considerations, for the sake of brevity. In practice, it will be necessary to modify the position of the point of application of the driving force, so as to avoid this source of derangement. In each case of application, I shall point out how the general

be allowed to have a twisting tendency, the one may be made to oppose the other, so that the same result shall be obtained as if the two forces acted directly in the lines required by the equilibrium.

In treating of the forces acting on the gas-vessel in motion, they may be considered as acting entirely in a single plane, namely, in that passing vertically through the long axis of the gas-vessel. For, however the power may be applied, or the weight may be slung, the resultant of the former must lie entirely in that plane, since, if the propellers are not articulated in that plane, they will be placed symmetrically on either side of it. And the latter force can, of course, have no tendency of its own to alter the set of the vessel, except that which is given to it through the change effected in the position of the centre of gravity by the propelling force; this change will be entirely in the same plane, therefore the reaction of the weight will be likewise included in it. The conditions of equilibrium may therefore be treated as those of a single plane, with respect to axes perpendicular to, and passing through points within, itself. Now the axis, about which the weight may twist the system, is one passing horizontally through the centre of buoyancy, corresponding in fact to the knife-edge on which, if the gas-vessel were a balance beam, it would be poised. And the propelling force must have no tendency to twist the vessel about any horizontal axis, and, consequently, none about the axis of buoyancy. This condition of no twisting may be ensured, either by so applying the force of propulsion that it shall not strive to disturb the level set of the system, or by so arranging the lines of action of the weight and of the power that, when the latter alters the position of the centre of gravity, the respective twisting tendencies of the two forces shall neutralise each other. In other words, then, the second alternative is, that the sum of the moments of these forces about the axis of buoyancy must be nothing. When this is the case, the direction of their resultant will pass through the centre of buoyancy.[1]

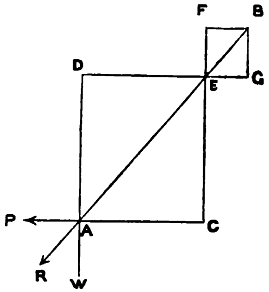
expression requires modification; as the conditions concerned in this point will be different in each class of air-craft.

[1] This will be evident from the following considerations. Let A (fig. 39)

Now, from the very nature of the air-craft, the propelling force will never be applied above the axis of resistance. If it is not applied in the horizontal plane passing through that axis, so that its resultant shall coincide in direction with that line, it will

be a point in the system, at which the directions A D, A C, of the resultants of the two forces, namely, the traction (P) and the weight (W), horizontal and vertical respectively, intersect. Let B be the centre of buoyancy of the gas-vessel. W and P may be supposed to be acting at A. Draw A E in the direction of their resultant, (R), and let A E represent that resultant in magnitude, E being any point in the rigid gas-vessel. From E, draw E D, E C, perpendicular to A D, A C. Then D A, C A may be taken to represent (P) and (W) respectively, in magnitude and direction. And the point of application of the resultant (R), may be supposed to be transferred to E, and E D = C A, and E C = D A; therefore resolving (R) into its components at E, E D, E C may be taken to represent (P) and (W) in magnitude and direction, or $\frac{ED}{EC} = \frac{P}{W}$. Now from B draw B F, B G, horizontal and vertical respectively, and produce D E, C E to G, F. B G, B F, then, are perpendicular to the directions of E D, E C, and express the ratio of their distances from B. Therefore, the tendencies of (P) and of (W) to twist the system about B, or the moments of (P) and of (W) about B, are represented respectively by $P \times BG$, and $W \times BF$. Now, these forces are tending to turn the system in opposite directions about B, and the condition is, that the sum of their moments must be nothing. Therefore, we must have

Fig. 39.



$$P \times BG - W \times BF = 0,$$

that is $\frac{P}{W} = \frac{BF}{BG}$; but $\frac{P}{W} = \frac{ED}{EC}$;

therefore we must have

$$\frac{BF}{BG} = \frac{ED}{EC}, \text{ or } \frac{GE}{BG} = \frac{AC}{EC}.$$

That is to say, the triangle B G E, must be similar to the triangle E C A; since the angles included between the homologous sides are equal. Therefore the angle B E G, must be equal to the angle E A C. But since E G is parallel to A C, these angles cannot be equal, unless B E is in the same straight line with E A. In other words, the direction of the resultant of the power and the weight must pass through the centre of buoyancy.

be applied below it. The problem then becomes this:—To apply the propelling force, at points below the axis of resistance, in such a manner that the weight of the burden shall neutralise the tendency of the former force to derange the level of the system. Now, the horizontal force being applied in a forward direction below the axis of resistance, will tend to advance the lower part of the vessel, while the upper part remains behind, and therefore to tilt the head of the gas-vessel up, and the stern down. It is evident then, that, to enable the weight of the load to counteract this twisting tendency, its centre of gravity must be thrown forward, in front of the vertical line passing through the centre of buoyancy, for, when thus disposed, it will strive to bring the fore end of the vessel down, and to allow the hinder extremity to rise.

We may now endeavour, according to these principles, to apply our propelling force to our air-craft—taking each class in succession.

Of the first class, the mere balloon—the limbless monad—is the elementary type. With this, of course, we have nothing to do, as we can only be considering structures in which development has advanced more or less. Our rudimentary gas-vessel must throw out some signs of limbs, before it can claim notice. Now among the aerial schemes, to which I have referred in my former part, are a few which may, perhaps, be referred to this head; such, namely, as involve the uniting of all parts of the air-craft into a single rigid body, by a fixed framework. They would nearly all fail (even if they had provided sufficient power, and propellers large enough), from not applying their motive force in the right place. In such an air-craft as this, there is only one mode in which the force can be brought to bear upon the system in an effective manner, that is, by causing it to act directly upon the body, so that it shall have no tendency at all to twist its position. For the alteration in the arrangement of the load, which would be necessary as soon as propulsion commenced, would be so great, if the propelling agents were attached as low down as the gallery at the bottom of the vessel, that the inconvenience, and liability to upsetting, would be intolerable. The force therefore must be applied as near as possible to the plane of the axis of resistance, and since, for this end, the propellers must be fixed to the sides of

the gas-vessel somewhere, they had better be at that part where no shifting of the load will be required when motion ensues, as the difficulty of working them would be fully as great if they were articulated to any other part of the gas-vessel. Again, it would be extremely inconvenient and unnatural to make the propellers work in any plane passing through the axis, except in the horizontal one. For instance, if there are to be two propellers, one on each side, no one would think of fixing one at the top, the other at the bottom of the vessel, or in any other positions but such as are on opposite sides of the figure, and on the same level. This, then, is the only case to be considered; and it resolves itself into two, according as one or more propelling instruments are used. If there is to be but one, there is but one point at which it can be placed, namely, at the extreme stern end of the axis, for this is the only point at which it will not either produce no effect in moving the system, or cause a rotatory motion of the vessel round a vertical axis. But this case is not likely to be put in practice, for it involves an extreme degree of nicety of adjustment that is scarcely possible, especially in the case of vessels of considerable length; for it is evident that, unless the force act exactly in the direction of the desired motion, it will be liable to be wasted in twisting the vessel round, so as to make it spin about an axis lying across its length. A single propeller fixed at the fore end of the vessel, would not answer the purpose, unless it were fixed at a considerable distance in advance of the head, so as to get free air to work in; and to fix it favourably for this purpose would be extremely difficult. Now this first arrangement of a single stern propeller may be made, either with a jet of aeriform fluid, on the rocket principle, or with a screw-vane: not very easily with any other appliance, such as an alternately striking fish-tail, but possibly. If there are two or more propellers, they must, of course, be arranged symmetrically on opposite sides of the vessel. This second form may, of course, be managed by any kind of driving agent that can be fitted to the vessel. However, the difficulty of adopting moving mechanism to the side of such a body as our gas-vessel must necessarily be would be greater than any that is involved in the construction of the higher forms of air-craft hereafter to be described, and the

arrangement, when complete, would not present sufficient advantages to make it likely to come into extensive use, so that I shall not occupy much space in designing forms of adaptation for this case, mentioning a few as possibilities, not as much to be recommended for service.

The simplest example is, of course, that in which human muscular power is applied directly to wings worked alternately as oars. This might be contrived in the following manner:—The rowers must be perched on small seats with outrigger rowlocks, at the side of the gas-vessel, on a level with its longer axis, as represented in fig. 40. There might, of course, be only two of them if the vessel was small; but they would find it difficult to keep time with each other, as one could not see the other's stroke. There must, I think, be an uneven number of rowers; one of them sitting at the extreme stern, as at B, fig. 41, and pulling a wing-scull with each hand, so as to give stroke to both sides of the vessel. If there were several rowers, they would be set in places on a gallery running round the equator of the vessel, as A C B in fig. 41, which represents one side of a fourteen-winged vessel with

Fig. 40.

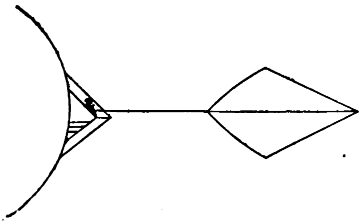
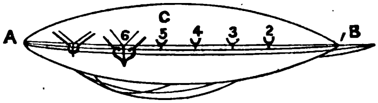


Fig. 41.



seven oars on each side, two, one of each set, being pulled by 'stroke' at B. Such a craft would, of course, require to be heavily ballasted by a burden fixed along the middle of its bottom towards the fore end. This would be absolutely necessary, to maintain the vessel in stable equilibrium in its proper position, for, without such burden, it would, of course, be easily upset, as the rowers on the opposite side would just balance each other about

the axis of buoyancy, like two boys on a see-saw. The centre of gravity of the system must be brought down as low as possible, to give it stability. The ballast must be placed somewhat forward to balance the weight of the 'stroke oar' at B, for there would, of course, be no rower towards the beak of the vessel to counterpoise him. The ballast, of course, would be the proper cargo, live or dead, of the craft. Such a system is, of course, the analogue of a centipede, or of an eight-oared gig.

A somewhat higher species of organisation, still of the same class, next claims notice. It is that in which the propelling instruments are concentrated into the smallest number, consistent with the lateral bi-polar arrangement, which is found in all advanced animal forms, that is into two, and in which they are driven by mechanical power concentrated in a separate organ; the whole system being still, whale-like, gathered up into one undivided body. Generally, of course, the power will be placed at the bottom of the vessel; and since it would be more difficult to adapt to the sides of the gas-vessel any reciprocating mechanism of sufficient strength and complexity to drive, backwards and forwards, large wing-wafts, than to manage the effectual movement of rotary instruments, I shall first take the case of the latter. Previously, however, I may state that, if the direct action of a jet of gaseous matter be applicable with good effect, it might be found useful under this form of fitting; the gas or steam might be generated underneath the vessel, and led by pipes up to each side at its equator. If heat were used as the prime mover in such a system as this, where, the whole apparatus being in one body, the source of power must be quite close to the gas-vessel, it would be requisite to have the lower part of that structure made of, or covered with, metal for protection.

Now our rotary propellers may revolve, either in a plane parallel to the long axis of the vessel, or at right angles to it. In the first case, they must be 'blowers,' or fan-blasts, enclosed in a case; in the second they must be screw-vanes. I shall select the latter for illustration, as being the simplest; this is in fact exactly the kind of apparatus which was constructed by M. Jullien, and to which I have already called attention.[1] This

[1] See p. 45, above, and 'L'Illustration,' November 22, 1850.

arrangement is represented in the diagrams, figs. 42, 43. Here A A′, is the body or gas-vessel; B, the driving-wheel, connected by endless bands with pulleys on the axles of the screw vanes. C, D, E, F, G, the frameworks that support H, H, the screws. The screws which, for simplicity, I have represented as each a single turn of a single thread plane, both of them twisted, and also revolving in the same direction, should certainly be, to do any real work, fully as large in proportion as those I have represented, that is of the same diameter as the vessel itself. They must be fixed on strong frames of bamboo, or of metal tubes, to

Fig. 42.

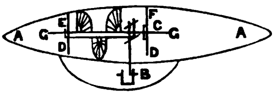
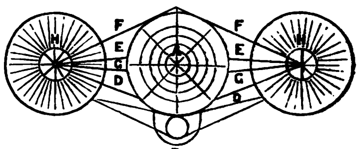


Fig. 43.



keep them in their places, clear of the vessel. Of this framework, D D are struts, for the purpose of keeping the screws up from below; E E, are rods for keeping them out from the vessel; F F, are ties supporting them from above; G G, are struts for keeping them steady fore and aft, and for transmitting their propulsion to the vessel. It will be seen that, with wheels of such large size as these must be, the supports of the two ends of their axles must be separate frames, each relying solely upon itself for firmness and security. For the supports could not be united to each other by ties that could confer any additional strength, without a useless addition to the weight of the system, as any such connections would have to run out to a great length laterally, to get round the breadth of the wheel. To divide therefore the duty of transmitting the force of the propellers to the body between the two supports, such an arrangement must be made that, in whichever direction the vessel is moving, forwards or backwards, one of the frames must be enabled to receive, and to transmit, the pressure as a thrust, and the other as a pull. For this purpose the pivots of the axles must pass completely through their sockets, and must have keyed on their ends, outside the latter, strong

shoulder-nuts which, when required, shall drag against the bearings, and so communicate the force to the framework, while on the inside of each bearing, the axle must be likewise enlarged into a shoulder, which shall press forward on that side when the motion is in that direction.

The reciprocating wing may be adapted to this form of air-craft, in the manner represented in figs. 44, 45, a front and side view respectively of a winged gas-vessel. A, the body of the vessel; B, B, the wings or sweeps moving to and fro in a horizontal plane, and furnished with a feathering adjustment for the return stroke. The wings are jointed to the body of the gas-vessel on vertical hinges at C. D is a sprit or mast, stepped on the top of the gas-vessel, and fixed by the stays, D E, D E. D must stand exactly in the same vertical plane with the joints C. The object of D is to give a point for the suspension of the winged

Fig. 44.

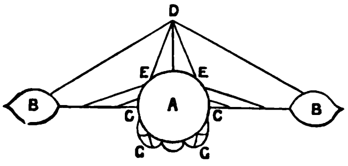
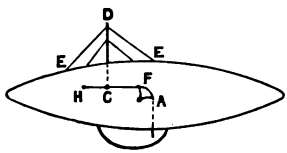


Fig. 45.



sails. That the latter may produce a good effect in propulsion, their blades must be of large area, and their arms of considerable length. The weight, then, of each wing will be great. They will be slung by wire cords, extended from the sides of the gas-vessel to the wing-beams, and from the mast D to the back of the blades themselves, as shown in fig. 44. The moving power may be transmitted to the propellers from the boat by the bell-cranks G, G, being derived from a single-acting reciprocating engine, adapted to exert its whole force in one direction. The effective stroke being thus made by the engine, the recovery of the wing may be effected by a spring of steel, or of vulcanised caoutchouc, which was stretched by the prime mover during the preceding movement. This is perhaps the simplest form in which the force could be communicated to the wafts. The same end might also be effected, without transmitting the force from the engine below

to the wing, by means of condensed air. For this arrangement, the wing-arm might be connected with a small cylinder and piston, attached to the gas-vessel, and worked by the air, forced by a process through a tube running up from the boat. This mode of conveying motion, however, involves considerable loss, which is entailed by the friction of the air on the channels through which it is driven.

In this general treatment of the case of the elementary air-craft, I have not considered the inertia of the system. Now the vessel must itself have weight, and there will be a burden attached to it below. This will throw the centre of gravity of the vessel below the axis of symmetry. Now, if there were no resistance of the air to its motion, it would be necessary to apply the propelling force in the horizontal line passing through the centre of gravity, to avoid the formation of a couple with the inertia of the body, tending to twist it in the opposite direction. It is evident therefore that the force must be made to act on the system, somewhere between the centre of gravity, and the axis of resistance. In practice, the point of application will be a little below the greatest thickness of the gas-vessel. The final adjustment of level will be made in every case, by arranging the position of the centre of gravity in a horizontal direction, by which means equilibrium may be always established, by forming a couple in any desired direction, between the burden and the buoyancy of the gas.

I think it will not be denied that, providing sufficient power is applied to the driving-wheel, such a vessel as this must progress at least as fast as any water-steamboat that has as yet been built. The reader, of course, remembers that, though I use the short spheroid 4 | 8 for illustrations in all my diagrams, because, being short, it takes up little room on the paper, I am always supposing, when I speak of travelling with velocity, that the vessel is of far finer form, approaching to that of an arrow. This shape the steamers cannot assume, for fear of breaking their backs some day across a wave or a sandbank, and so our air-craft may attain to a swiftness of which the water-boats cannot dream.

We may now pass on to the next class—the dual arrangement—in which the craft is divided into a gas-vessel, and

working burden to be suspended from it. This may be considered in two groups:[1] the first, that in which a single man is to fly alone; the second, that in which a boat is to be propelled. The latter embraces almost all the forms in which the art has yet been attempted; the eggoon and car is its type.

First, then, of the system organised for simple flight. This may be considered as the elementary form of the second stage of development. In this case, then, the problem is, to hang a single man, provided with the mechanical apparatus of flight, from a gas-vessel, in such a manner that, when by muscular exertion he works his propeller, his whole force shall be available for directly overcoming the resistance of the air to his float; at least, that none of it should be wasted in lifting him, or in throwing the gas-vessel out of its proper level. I am not aware of any endeavours having been made to put in practice this very obvious and tempting application of simple principles, except that which was made by M. Degen at Paris, subsequent to his efforts at mechanical flying at Vienna. I have not been able to find any account of his experiment, except that the mob thrashed him.[2] A hint towards the attempt I have already quoted from Mr. Wise.[3]

We need not here consider by what means the motion of flight is to be accomplished. We must first ascertain how our man is to be slung; in future chapters we shall consider his wings, and his means of driving them. In the last case, of the gas-vessel armed with propellers, I was obliged to speak of the instruments more specially, because the mode of arrangement there depended on the sort of mechanism that was to be adopted. In the present instance, it matters very little how the flight is to be effected; the mode of suspension will remain the same. The difficulty is not as respects the attachment of the man to the gas-vessel, but rather of the gas-vessel to the man. It would be superfluous here to show how he must not be hung; that is already abundantly evident from the discussion of the ordinary

[1] See p. 193, above.

[2] See M'Sweeny, 'Aer. Nav.' 2nd edit. p. 99; 'Mech. Mag.' vol. i. p. 11 Turgan, 'Ballons,' p. 171; Delcourt, 'Manuel,' p. 22.

[3] See p. 126, above.

mode of balloon rigging, which was entered into in the first part of this book.[1] I will here endeavour to show how it may be done.

But first let us gird up the man for his journey. He must, of course, be slung so that his position may be easy, and that his limbs may be perfectly free. His body must, of course, lie level, when he is progressing with speed horizontally through the air. This will be necessary for the purpose of diminishing the resistance of the air to his figure. He may therefore be slung, either with his face or with his back, downwards, just as a man may swim in either attitude. The former mode would, I should think, be preferred, unless occasionally when the route might lay over the sea, or across an immense plain. It would, however, be desirable that he should be able to change his position. Now, men cannot, excepting always Hindu Faquirs, be hung by hooks inserted in their flesh, neither can they grow wings to their shoulders.[2] Our flyer must therefore be furnished with a framework, to which his wings may be jointed, the gas-vessel may be harnessed, and himself slung. This should be made of steel tubes, for strength and lightness. He may shift his attitude when suspended, either by altering the position of his centre of gravity, or by changing the point by which he is suspended. He could

[1] See Chap. II. above.

[2] What a pity it is that artists, even masters, will paint and carve human figures with wings. Everybody who has ever dreamed in sleep of flying, must have felt a conviction that there is in man an undeveloped capacity for locomotion through space. But those who have felt this know too, that their fancy has required no wings, or mechanical exertion of any kind for this floating motion. This is an idea which must be realised if at all without machinery. The furnishing of angels with wings springing from their shoulders, is fully as false as it would be to decorate them with epaulettes; not only false to the anatomy of the body, but false to the conception of the spirit. Every perfect painter could represent a human figure as flying, by simple expression in the outlines of the body; even of the face alone. If, not being a perfect poet, the designer must have recourse to mechanical artifice, he might draw his wings as symbols, and place them near the body, as if attached, but he should not stick them to it. The shoulder wings are a clumsy device, suggestive at best of mythologic lore, not prophetic of the destiny of man. It is only the mechanical man that requires wings to propel him through the air. The real man flies without them.

not turn completely over in the air, without an arrangement for effecting this latter movement; but it would be inconvenient, and it might be dangerous, to have to do this when unnecessary; therefore he must also be supplied with the means of making the former adjustment, to relieve him from the necessity of altering his suspension whenever he wishes to change the inclination of his body.

These conditions will be answered by the following arrangement:—Let the body be enveloped in a skeleton-frame or waistcoat-cage, considerably larger than the body, which may be introduced into it by simply slipping it over the head. It should surround the trunk, without touching it in any part, when held up, so as not to rest upon the shoulders, coming, however, pretty close to the sides, of which it should follow the curvature, especially under the arms, but allowing several inches of room between the back and front rods, and the corresponding parts of the body. The frame is represented in figs. 46, 47, which present respectively a back and side view of the apparatus. The bars will form a complete cage for the trunk, leaving, however, spaces at the shoulders for the arms and head to pass through. A bar will lie across the shoulder on each side of the neck, comfortably curved and padded within, to receive the forward pressure of the shoulders during the flight. The lower part of the cage will just descend to the hips when resting above on the shoulders, so as to leave the lower limbs completely at liberty. Along the front of the cage and outside, parallel to the backbone, will run a rod on which a weight traverses from end to end, so as to be fixed by a binding screw at any point on the length of the rod. And about the centre of the middle bars of the front and back, must be firmly attached a strong ring of the cage. Other pieces will have to be added to the framework, for the purposes of flight, but these are all its

Fig. 46.

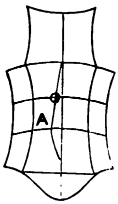
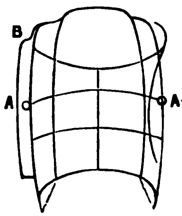


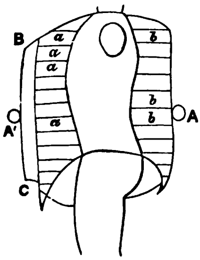
Fig. 47.



rigid parts that are required for the suspension, which is the object to which our attention is now to be confined.

To complete the attachment of the flyer to his cuirass, it must be furnished with a strong under-girth or saddle-strap, which, when the victim is in his cage, shall prevent him from slipping out of it downwards, even if all his supports, which we have now to describe, should break. Before this coat of mail is put on, our flyer must invest himself with a more comfortable under-garment. If he were to fly entirely with face downwards, and not desire to change his position, it would be sufficient to cover the fore part of the body with a spring-cushion or air-pillow, which should rest upon the front part of the cage, and sustain his weight without distressing any one part by the pressure. If, however, he desires to turn over in the air, he must have another kind of appliance: for such a pillow before and behind would be a kind of clothing rather too warm for vigorous exercise. This, I conceive, may be managed in the best and safest manner by encasing him with some light, strong, elastic stays, with a double set of girths or ties attached to them; one set having their free ends in a row along the back, the other along the front of the body. These bands should be made of vulcanised caoutchouc, and should have their outer ends buckled to a row of loops, on the back and front bars respectively of the framework, so that, in whichever direction the man is placed, whether back or face downwards, he will be slung from within the cage from its upper side by the elastic bands. His appearance, as fitted in the cage, will be represented in fig. 48; the frame-case being section; *a a a*, *b b b*, being the elastic bands or suspenders.

Fig. 48.



The rings A A′ are for the suspension of the whole apparatus to the gas-vessel. Only one of them is to be used at a time; A or A′ will be hooked to the suspending line, according as the man wishes to fly face or back downwards. This line must terminate in two branches, each six or seven feet long, and each of the same strength, namely, sufficient to bear the whole strain of

the weight of the man and his appendages, together with the force of traction. Only one of these therefore need be doing service at once. When the flyer wishes to shift his position from face earthwards to face skywards, he will seize the end of the free branch in one hand by reaching behind him to A, will pull himself round sideways till he can grasp it with both hands, and will then fix its hook in the ring A′; he will then be hanging side downwards by the two hooks; feeling himself secure, he will then release the ring at A from the hook, and will now be hanging back downwards from A′. If he should find it a difficult manœuvre to change back again, he can have a ring at his side, and can so complete the shift in two operations. Woe betide him if he makes a mistake, and slips one hook before the other has hold!

The use of the rod and weight in front, B C, is for adjusting the position of the body, by shifting the ballast to different points of the rod, so as to alter the position of the centre of gravity. It will be seen at a glance that, if the system be hung by A, or by A′, the position of these rings being such that the body will lie exactly horizontally, and if now a certain weight be hung at B or at C (fig. 48), the body will be inclined downwards towards the head, or towards the feet respectively, so that the position of the whole person will depend upon the point at which B is hung.

Our flyer is now ready to be slung to his float. The end to be attained is, to transmit his propelling force to the gas-vessel so that there shall be no tendency to twist it out of the horizontal set. In the case which we have already considered, namely, that of the single-bodied air-craft, this is simply attained, by making the forces act directly in the same plane with the axis of resistance to motion. When, however, as in all the cases which remain for us to consider, the source of power is to be suspended below the gas-vessel, this solution of the requisite is impossible, and another must be found. One condition is certain, that if the gas-vessel lies horizontally at starting, the suspending links must be flexible, not having fixed joints; for, if the system be rigid, it is at once evident that an impulse given horizontally to the weight below will not move the float above in the required direction, but that a 'couple' will be formed, tending to twist the system about a certain axis of gyration, and having no resultant

at all. The power must therefore be slung by links, having flexible joints, or by ropes. If, then, the gas-vessel were in a horizontal position before, it can be so no longer when acted on by such a force. The problem then becomes—To sling the power by ropes to the float, so that the resultant of the traction communicated by them to the latter, shall coincide in direction with its longer axis.

The chief peculiarity which distinguishes this our first case from the others that will follow it is, that the burden is to be suspended by a single point of its own body. This, which will not be the case in the more complex structures, involves differences in the mode of solution of the problem. There are again, in the two cases, two methods of harnessing the gas-vessel to our elementary burden. Each of these will admit of some modifications, which I shall describe in turn. The suspending cords transmit, of course, to the gas-vessel both of the forces acting upon the flyer: his weight and the propulsion which he exerts. And it is evident, from what has been said before, that if the cords be attached to the float at points not lying in the plane of the axis of resistance, the propelling force must have a tendency to twist the system. They therefore must be attached to the gas-vessel at points either lying in the plane of the axis of resistance, or at such points below that plane—for they cannot be applied above it—that the tendency of the traction to turn the head of the gas-vessel up shall be exactly compensated by the tendency of the weight to bring it down. Again, each of these cases is divided into two, by the consideration that the weight may be slung by cords attached to points lying in one plane across the gas-vessel, or by cords attached at different parts of the length of the figure.

Firstly, then, the flyer may be suspended by cords lying in a single plane across the gas-vessel, and so that the propelling force shall act directly in the line of the axis of resistance. There is but one way of effecting this, and that is a very simple one: he must be hung by two cords, attached to the gas-vessel at the extremities of a horizontal diameter passing through the axis of resistance. The conditions to be attended to in this case are these: first, the points of attachment of the cords to the gas-vessel must be at least no farther from its beak than the middle of its length,

and should be further forward than this point. For if not, the vessel when exposed to the resistance of the air will be in a position of unstable equilibrium;—as respects the direction, in a horizontal plane, in which its head shall point—the resistance tending to turn it round head-aft on the slightest deviation from direct action in the line of the flight. The further forward the diameter, by the extremities of which the vessel is drawn on, the more will the resistance of the air tend to keep it in its proper position. But, the further forward the points of suspension are taken, the more counterpoise will be required to keep the tail end from rising by its own buoyancy. The vessel must of course be balanced as nearly as possible upon the cross axis of suspension. The second point to be regarded is, that the gas-vessel be strong enough in every direction to sustain the strain thrown upon it by the weight acting at a single point of its length. There will be no case in 'aerial navigation' in which the gas-vessel will be subjected to such severe trial of its stiffness, as in this and the next following instance. I believe, however, that the hints which I have given in a former chapter will be sufficient for the purpose. Thirdly, the suspending cords must be kept apart below the gas-vessel, so that the weight hanging to them shall not cause them to converge, and so dip the vessel below its horizontal diameter. Because if this happens, the propelling force will in fact act upon it at the points where the cords leave it in the direction of tangents to the curve.

Now as to the actual suspension. I would encircle the gas-vessel with a strong hoop of bamboos, of the same diameter as the vessel at the point selected for suspension. Two or three other slighter hoops should girdle it at certain points towards the head, and towards the stern these should be tied by longitudinal cords to the main hoop, the object of these being to receive the traction from the main hoop, and to transmit it to the gas-vessel, and to keep the former in its place. The same object might be attained by enveloping the gas-vessel in a netting fastened to the central hoop. The object of girding the gas-vessel in this manner, is to avoid the necessity of having a solid axis through the centre of the gas-vessel, which would otherwise be necessary, to give, by its free ends, points of attachment to the suspending ropes. A

strong cord (wire rope) should now be passed over the upper semicircle of the main hoop, and firmly bound down to it over the whole of this arc; and at each extremity of the horizontal diameter it should be clamped to the hoop by strong bandages of metal. Immediately below this point on each side, the rope must itself terminate in a strong iron ring lying parallel to the side of the gas-vessel. To these rings must be linked the cords (wire-rope) by which the burden is to be slung. At a point on the length of the suspending ropes, somewhat further from their attachments to the hoop than the distance of the points of suspension from the beak of the gas-vessel, the two cords should be attached to the extremity of a rigid bar, stiff and strong enough to bear without bending or breaking the thrust upon its two ends, caused, as will be seen, by the weight of the flyer hanging below it. This might be made of bamboos, thickest in the middle, or better still perhaps, of metal tubes, oval in section, with the long axis of the oval vertical, and thicker towards the middle than at the ends. The length of this should be somewhat greater than the diameter of the gas-vessel at the point of suspension, in order to keep the cords well clear of the vessel, so as not only to prevent them from clasping it, but to relieve its sides from the crushing force exerted by the weight upon any object tending to keep the cords asunder. It will thus also allow the float free motion in a vertical plane about the axis of suspension. The object of this latter arrangement is to enable the vessel, when not in use, to lie in the air, with its length in a vertical direction, and to give facility for alighting in places where there might not be much room, the vessel being thus made to occupy the least possible amount of space horizontally. From this bar, then, the cords must be brought down, converging symmetrically to a point at some distance below, where they must be united. Of course the longer these limbs of the cords, the less will be the compressing force exerted by the weight on the horizontal bar. From the apex of the triangle formed by the joined ends of the cords, the line, or rather the two branches, must descend, by either of which the flyer may be hooked to the float. Finally, the gas-vessel must be furnished with a small shifting weight attached to an endless cord reeved through two

pulleys on the middle line of the bottom of the vessel, one near the end of the tail, the other just under the point of suspension, or towards the head. The free loop of this cord will be carried down to the flyer; its use being to enable him to alter at will the inclination of the axis of the gas-vessel, and to keep it strictly horizontal. The following figures represent this species of air-craft in different views.

Fig. 49 shows the flyer with his gas-vessel in the position of preparing to start, which he does, of course, by springing from the earth with his legs. He has also just harnessed to his shoulders the float, which has been riding at anchor in the position represented in the figure. I have not represented any wings or propelling agents, firstly, because we have not yet come to them; secondly, to avoid complication, for I wish my figures to be as simple, and as nearly approaching to the nature of mere diagrams as possible.

Fig. 49.

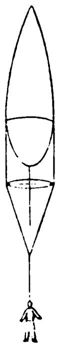


Fig. 50.

Fig. 50 represents an end view of the flyer and float in the air, just before commencing to go ahead.

Fig. 51.

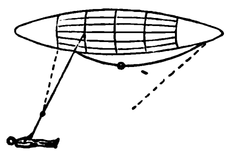


Fig. 51 is a side view of the same in the position of flight. I need scarcely repeat that in this case the propelling force has no tendency to tilt up either end of the gas-vessel. I think all the parts I have described will be recognised in these figures without any special references. I have not continued the ballast line down to the flyer, lest its limbs should be mistaken for suspending cords.

I have drawn the gas-vessel in proportions as respects size not less than those which, in practice, I suppose it would bear to its human burden. I conceive that the man and all the apparatus will certainly not weigh more than five hundred pounds. Now it appears by the table[1] of sizes that a gas-vessel of the provi-

[1] See Appendix D. The man may weigh 160 lbs. The gas vessel (containing 7,310 cubic feet of hydrogen) has about 2,540 square feet of surface.

sional form must be about eighty feet long, and thirteen and a quarter in diameter to lift this weight. So if our man is six feet high the gas-vessel will be a little more than thirteen times his height in length, and two and two-tenth times in breadth.

Now for the species next in order of simplicity. This is the case in which the suspending cords are still to be attached to the gas-vessel in one vertical plane perpendicular to the long axis, but at points below the extremities of the horizontal diameter, and therefore below the axis of resistance, as, for instance, is represented in the diagrams figs. 52, 53, 54, which are supposed to be vertical sections of the gas-vessel, through the plane of suspension. I shall select that shown in fig. 54 for illustration, as being an extreme case and the simplest. The construction of the system will be the same as in the case just described, except that the girth cord will be bound to the hoop round its whole circumference, and will be furnished with a single ring at the middle of the lower semicircle, from which the weight will be suspended by a single cord.

Fig. 52.

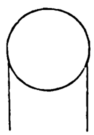


Fig. 53.

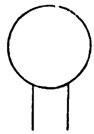
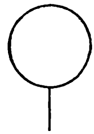


Fig. 54.



It is clear that in each of these cases the propelling force, being applied below the axis of resistance, will have a tendency to turn up the head of the vessel if the point of suspension is directly under the centre of buoyancy. And this tendency will be the greater, the greater the distance of the point of suspension, that is, of application of the force from the axis of resistance. It will be greatest in the case I have taken, in which that distance is at the maximum.

The envelope may be made of strong silk thickly varnished, which may weigh ·05 lb. per square foot (See Appendix B). Now 2,540 × ·05 = 127 ; the whole envelope therefore may weigh about 127 lbs. Now 127 + 150 = 277 ; this therefore leaves (500 − 277 =) 223 lbs. for the weight of the framework of the gas vessel, the shifting ballast of both man and float, the man's waistcoat-frame, and his wings : and I do not think this is too little.

Let now fig. 55 represent the gas vessel with man, A, hanging by a single cord from a point, E, at its bottom, exactly below the centre of buoyancy, B. It is clear that, so long as the system is at rest, the gas-vessel, if its own centre of gravity is directly below B, will float perfectly level. It is equally evident from what has been said before,[1] that as soon as the man begins to strike out, and horizontal traction is exerted, the fore end of the vessel must be tilted up; and the greater the speed the greater will be the derangement of the level. For the cord A E, transmitting the forces of gravity and of traction from A to E, must represent the direction of their resultant, and, as was shown, the position of equilibrium for the gas-vessel is such, that the right line between the point of action of the forces and the centre of buoyancy must be in the direction of their resultant.[1] The vessel therefore

Fig. 55.

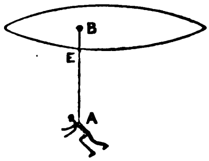
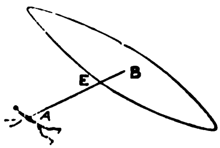


Fig. 56.



must be tilted up till the line E B coincides in direction with the suspending line A E (fig. 56).

Now this tendency may be obviated by altering the position either of the centre of gravity of the gas-vessel, or of the point of suspension. But it must be remembered that, for the purpose of keeping the vessel's head always foremost, the point of suspension should be considerably nearer to the head than to the tail end, and therefore may, with advantage, be thrown in advance of the centre of buoyancy; and that thus by properly adjusting the position of the former point, both of these requisites may be attained at once. When after the adjustment it is found that as the speed varies there is a tendency to turn up or down in front, the balance may be secured by a shifting weight traversing between the beak and the point of suspension, or a little aft of that point. The proper position for the point of suspension will

[1] See note, p. 291, above.

be ascertained in the following manner. Let the gas-vessel be first ballasted, so that when filled with hydrogen it shall float with its long axis horizontal. Let now the weight of the man and his suspending frame and wings and cord be ascertained, and also the power he can exert in propelling. Suppose now the man (160lbs.) together with his appendages weighs 200 lbs., and that he can exert a force by the alternate flexure and extension of his legs equal to a pressure of twenty pounds. Then we must have in fig. 39,

$$\frac{GE}{BG} = \frac{AC}{EC} = \frac{P}{W} = \frac{20}{200} = \frac{1}{10};$$

that is to say, if in fig. 57—B being the centre of buoyancy, and C the point at the bottom of the gas-vessel that lies perpendicularly

Fig. 57.

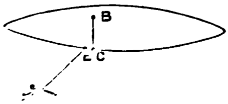
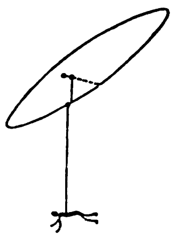


Fig. 58.



below B when the vessel is horizontal—C E be measured towards the head of the vessel $= \frac{1}{10}$ B C, E will be the point from which the weight should be hung so as to keep the vessel horizontal, when moving with such velocity as would be produced by a pressure of twenty pounds acting in the direction of its length. Of course, if the vessel is harnessed by this point it will, when at rest with its burden suspended to it, or when moored with the whole rising power due to its full burden, float with its stern end tilted up till the centre of buoyancy is exactly over the point of suspension, as in fig. 58.

But this end of preventing the tilting may be equally secured, without any special arrangement of the point of suspension, by properly ballasting the gas-vessel. This, of course, may be effected by a shifting ballast attached to the gas-vessel, so that its position may be altered at pleasure, as by a weight fixed upon a cord travelling over two pulleys fore and aft, on the front part of the length of the vessel. The greater the distance travelled over by the

ballast the less need be its weight. With this adjustment then, the flyer may be slung from a point immediately below the centre of buoyancy of the float.

But this may be contrived by a still simpler method; and the same remark applies to the travelling weight for keeping down the tail end of the gas-vessel in the preceding case. It is clear that the load already hanging to the float is quite as well able to keep the ends down, if they were tied to it, as any accessory weight can be. Thus in the former case, in which the centre of buoyancy is behind the axis of suspension, and on the same level with it, the tendency of the tail to turn up may be prevented, and the inclination of the gas-vessel regulated, by a cord attached by one end to the lower part of the front near its stern, and by the other to the apparatus of flight below. By this means the flyer may haul the stern down, and by tying the line to his body-frame may fix the gas-vessel in any required position. This, of course, amounts in fact to throwing a share of the weight of his body on the tail end—the more he shortens up the line the more of his weight the end pulled down has to bear. As the lifted end of the float is drawn down, the weight will be drawn towards it in a proportional degree. Similar remarks apply to the latter case of suspension, in which the fore end of the gas-vessel may have a tendency to be tilted upwards. By tying it down to the burden it may be kept horizontal, or inclined at any required angle. Thus in figs. 59, 60, the dotted lines representing the

Fig. 59.

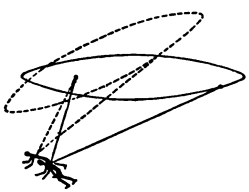
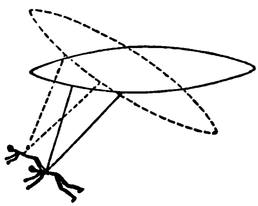


Fig. 60.



original inclination of the system, the continuous lines will represent its position when the end braces have been shortened up, the centre of buoyancy of the gas-vessel not having moved.

Now these secondary braces are in fact additional slinging

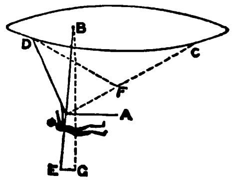
cords, and we have now arrived at another kind of suspension, that in which the flyer is hung by cords not lying in the same plane across the length of the gas-vessel. This case, like that in which the cords were all in one such plane, admits of being divided into two; first, that in which the cords are attached to the gas-vessel at points in the horizontal plane of the axis of resistance; second, that in which the points of suspension are below that plane. However, from a peculiarity of this elementary type of the second class, namely that the cords must converge to a single point on the burden, the practical difference between the two divisions of this case vanishes; because though the points of suspension are all in the axial plane of resistance, the gravitating force of the burden will not be equally transmitted through all the cords as soon as motion ensues, but will be thrown more upon the hinder than upon the fore, unless there be some special contrivance to prevent this. Or taking another view of the same peculiarity, since the cords converge from different parts of the length of the gas-vessel to a single point on the burden, a triangle is formed of which the base is that part of the length of the gas-vessel that lies between the points of suspension; the sides are the converging cords. This triangle forms virtually a rigid system, for the cords are kept straight and tense by the weight hanging to them; the propelling force therefore acting horizontally at the apex of the triangle can only tend to twist the system round, until by the change of position a new couple is formed, between the weight of the burden and the buoyancy of the float, which acting in a direction opposite to the former, keeps the system in equilibrium in the new position. This holds good equally whether the cords be attached at the axial plane of resistance, or below it. I shall therefore not consider the former case, because it only introduces the necessity of the additional complication of the stretcher-bar for keeping the cords asunder, without conferring any corresponding advantage. The conditions of the present problem are precisely those of the common eggoon with converging end-stays,[1] the inconveniences of which arrangement being inseparable from this form of air-craft, they must be combated.

[1] See chap. v.

For the sake of simplicity, I shall, as before, select for illustration the case in which the suspending cords are attached on the bottom line of the gas-vessel, in the vertical plane passing through the long axis of the figure, so that we have only one cord from each point of its length. Further, for the same reason, I shall first take the case in which there are on the vessel only two points of suspension to which the suspending cords are attached, one on each side of the cross-plane passing through the centre of buoyancy, and at equal distance from the two ends respectively.

Let now in fig. 61, B be the centre of buoyancy of our gas-vessel; D C, the rings to which the suspending cords are to be attached. It is quite clear now that the action of the forces transmitted from the burden to the float will depend on the relative length, and consequently on the inclination of the depending cords. The ballooner's plan has always been to make them of the same length, and inclined, of course, at equal angles to the axis of the gas-vessel at each end, as D F, C F, in which case, of course, as soon as traction commenced at F, D would go up and C down. To ascertain how the cords must be proportioned, we must first ascertain in what direction the force is to be transmitted; this we learn from the general rule before deduced.[1] The resultant of the burden-weight and of the traction must pass through the centre of buoyancy. We must ascertain, then, the direction of this resultant thus:—Through B draw B G vertical of any length, and let B G represent in magnitude the weight of the burden (200 pounds we suppose), through G draw G E horizontal, and make G E represent the propelling powers of the flyer (20 pounds we suppose) on the same scale, i.e. P being the traction and W the weight, make $GE = \frac{P}{W} BG$ (that is, in our supposed case $= \frac{BG}{10}$), and join B E. B E is the line of the resultant of the traction

Fig. 61.



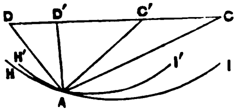
[1] See p. 291, above.

and weight, when the system is in uniform motion. The burden then must be somewhere, anywhere, on this line while the system is progressing with uniform speed. If, then, the vessel is connected with the burden by cords of such length as will admit of the flyer assuming a position on this line without throwing the vessel out of the horizontal, the required conditions will be satisfied. Let us now suppose the flyer to be suspended at A in this line by a single cord (as in fig. 58) from a point on the lower outline of the gas-vessel, exactly between D and C. The system will be in equilibrium, and the float will lie horizontal. While he is in this position, let us suppose cords to be stretched from D and C to A, and strained tight, so as not to alter the position of the vessel; the equilibrium will remain the same. Now let the cords A C, A D, be supposed strong enough to bear the whole weight of the man and his appendages without breaking; and let us suppose the gas-vessel to be firm and strong enough to resist the compressing force exerted by the weight, tending to crush C towards D, it is evident that we may now cut away the cord running from A towards B, and that the system will remain in equilibrium, and the gas-vessel horizontal. Thus, then, the flyer may be suspended by two cords, so as to fulfil the requisites of our problem. It is clear, too, that the cords may be multiplied to any extent, and may be brought from all parts of the vessel to A, provided the proportions of their length are such that they will not alter the angle between the line A B and the long axis of the vessel.

However, it may be deemed requisite to have means of altering the inclination of the gas-vessel at will, so that it may be kept horizontal, although the velocity of flight might be changed. Now this may be done by shortening all the cords, fastened to the vessel towards one end, and lengthening all those towards the other. But if there are many such cords, it will be extremely difficult to adjust the tensions of them all equally. Indeed the arrangement for changing the inclination of the gas-vessel can scarcely be contrived, except with the very simplest rigging of the sling-ropes. This will appear from the following considerations:—All the cords towards one end must be lengthened, all towards the other end shortened; if all these operations must

take place separately, or not at all, it would not be worth while to attempt it. It could only be suggested as practicable, if what was taken up from the length of each rope at one end was to be added at once to its fellow towards the other end. Now let us see what occurs if this is done. Let D C be the points of suspension; A the burden; let C A, D A be the sling-ropes from C D. If now C A is shortened and D A lengthened by the same amount, the same effect would be obtained as would ensue if C A D being a

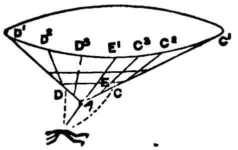
Fig. 62.



continuous cord were made to pass under a pulley or through a ring at A—A would be made to describe a certain curve with respect to the line D C. There is no objection to this, but the curve so described will be an arc of an ellipse of which D, C are the foci, as will be evident to anyone who remembers either the fact that the sums of the focal distances of points in an ellipse are constant, or the common method of drawing this curve with two pins and a string and pencil. Let H I be a part of the arc so described, the 'locus' of A. If now there be another continuous suspending cord reeved through A and attached to the gas-vessel at C′ and D′, as A is passed along this cord it will, of course, tend to describe another ellipse, of which C′ D′ are the foci, as at H′ I′. Now no two ellipses can coincide for any considerable length of arc. This mode of adjustment, then, is not admissible, except for very small angles of change, within which the curves of all the ellipses described by the burden about the several pairs of suspension-points might coincide. For in all positions of the vessel the strain would be thrown upon some one pair of points and their appropriate cord, to the exclusion of the others. However, the greater the distance of the boat from the gas-vessel, that is to say, the longer the suspending cords, the less will be the difference between curves described by A about the several foci of suspension, and therefore the more equally will the strain be thrown on the several cords. The error, again, might be compensated in some degree, perhaps sufficiently, by forming a part of each cord that comes down from each point of suspension, of vulcanised caoutchouc, which by its stretching would distribute the burden and relieve the several slings of undue strain. All the

suspending lines from each end would then be collected into a single cord, which would pass over a pulley at A, as represented in fig. 63. The parts of the cords between the cross strokes and the points C D, where they converge to one, are supposed to be made of vulcanised caoutchouc. The flyer would have the power, by means of a cord represented by the dotted line, of hauling down either end of the vessel, and of causing the rope C D to traverse through the pulley. By fixing this line he could fix the gas-vessel in any position. The system would be further strengthened by attaching a cord, E E′, to the gas-vessel and to the pulley immoveably; having in like manner a part of its length made of elastic material. This cord represents the radius of the circle, which is the limit of the ellipses of which C′ D′ etc., are the foci, E being the centre into which the foci have converged. Of course it need not be passed through the pulley, but would be attached to the block, as it is not one of a pair but does its work by itself.

Fig. 63.



But probably the simplest and most useful method will be that of slinging the flyer from two points of the gas-vessel (as in fig. 61), chosen so as to distribute the strain as fairly as possible between the ends, which will tend to turn up, and the middle, which will be subjected to compression. The vessel may be considerably relieved in this latter respect by retaining the middle cord as in fig. 61, which, if made partly of elastic material, will throw a part of the weight constantly on the part of the vessel to which it is attached.

It must be remembered that with this mode of suspension, if the cords are fixed with any given different lengths to suit any given speed, and if the position of the gas-vessel is thus made horizontal during motion, when it is at rest it will not float horizontally, but will lie just as much inclined to the level line, as the line joining the centre of buoyancy and the point of attachment of the cords to the burden was inclined to the vertical during the motion of the system.

I fear I have devoted more space to the solitary flyer than is due to the dignity of this amusement, but in establishing the

requisites for the elementary form, much of the work has been done towards providing for the fitting of the more highly organised craft, to which we must now proceed. I have only now to add that in the case of the flyer and simple gas-vessel, no modification has to be introduced into the requisites thus ascertained as respects the application of the gas-vessel, on account of the inertia of the system. The only inertia that will affect the gas-vessel will be its own, and since it is symmetrical about its long axis, the centre of gravity will be in it, so that its twisting tendency, due to the inertia, is provided for by the means already described. The same remark applies to all the rest of our bipolar class of two-bodied air-craft.

The next species of our double-bodied class is a boat rowed by a single man; this, however, will not require separate treatment, as the whole genus of air-craft, consisting of a gas-vessel and a boat, requires and admits of precisely the same mode of suspension. The other two species of the genus are, of course, that in which the boat is manned and propelled by several rowers, and that in which it is driven by artificial power.

It is perhaps possible to sling by a single point of its body a boat in which a single man can sit and propel himself. If so it must be done on the principles ascertained in discussing the direct suspension of a man's body; but I should not be inclined to try the experiment of balancing myself in such a vehicle. It would, of course, be impossible to do this with the least chance of safety with a vessel to contain more than one person.

There is, however, a method which is a sort of development of the single point suspension, by which boats of a considerable length might be hung from a gas-vessel so as to maintain the latter in the required position with its long axis in the direction of motion. It is simply that of collecting the converging cords in a single point, exactly as is represented in figs. 61, 63, and then suspending the boat by diverging cords from this point. It is evident, however, that in this case the propelling force will exert a tendency to tilt the fore-end of the boat up, twisting it in fact round the point from which its cords diverge. This tendency must be combated in exactly the same manner as the similar tendency of the gas-vessel has been counteracted. This

will be evident on inspection of the figs. 64, 65, 66. If the two vessels be symmetrically connected with the central point of convergence by cords of equal length stretched from their two ends, as in fig. 64, it is evident that as soon as propulsion commences in the boat, the whole system will be twisted round in a vertical plane without altering the relative position of its parts, as will be represented by turning the diagram as it lies under the eye through a certain angle in the plane of the paper. If, however, the twisting tendency be compensated as respects the gas-vessel by properly adjusting the length of its cords, as already described, the gas-vessel will become horizontal as soon as motion commences, and will remain so, but the head of the boat will still be turned up and the stern down, as in fig. 65. The only way of counteracting this is so to arrange the weight of the boat that, when propulsion commences, the weight shall just be moved out of its resting position by the twisting force to such an extent that, when the boat becomes horizontal, the downward pressure of the weight shall just neutralise the upward twist of the propulsion. This, of course, will be effected by throwing the weight as far forward as possible, and by so suspending the boat that

Fig. 64.

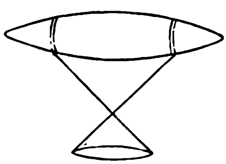


Fig. 65.

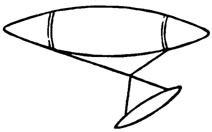
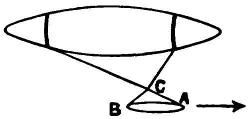


Fig. 66.



when it is horizontal, its centre of gravity shall lie in front of the vertical line through the central point of suspension. This will be the case if the fore cords, A C, are lengthened and the hinder cords, B C, shortened up as in fig. 66. It must be remembered, however, that if, when the forward motion ceases, the cord-lengths remain proportional according to this adjustment, the whole system will lie out of the horizontal, the stern ends of both boat and float rising, and the bow-ends falling, to enable the centre of gravity of the whole system to take its place exactly

under the centre of buoyancy of the float. If, therefore, this geometrically possible, but not very mechanically convenient mode of suspension be adopted, the lengths of the diverging cords of the boat must be altered as the motion ceases, otherwise the man-vessel will be thrown into a down-hill position, not very pleasant to the passengers. With this arrangement, then, one of the boat-cords would have to be wound upon a windlass at its point of attachment to the boat at A or B, so that the adjustment might be made by increasing or diminishing the absolute length of one of the cords. Or a simpler, and perhaps less dangerous expedient would be that of making the cord continuous from C, where both ends would be fixed, passing it over pulleys at A and B, and round a windlass cylinder between them, so that as the latter was turned in one direction or the other, the limbs A C, B C of the cord would be lengthened and shortened respectively or the reverse.

If, however, more than one cord is to come from the float, and more than one is to go to the burden, is it not needless to have two sets of suspenders, one diverging to each vessel from a point in the midst between them? The form which we have just been considering, is in fact only a particular case of suspension of the boat by a single point of its body, with the provision that the centre of gravity of the burden is placed so far below this point, that its position is one of stable equilibrium. What we have now to discuss then, is the development of our organism, by extending to the burden the same process of expansion which we have already followed in the gas-vessel—that of spreading out the attachment of the cords from a point into a line or number of points.

The simplest form of such arrangement is that in which, as in the ordinary eggoon and boat, cords are made to converge from the extremities of the gas-vessel to the extremities of the burden,[1] not, for the present, considering the other intermediate sling-ropes. But with our stiff gas-vessel it is not necessary to hang the burden from its extreme ends. We may attach our sling-lines to any other points in its length. First then, we may hang our boat by two or more points of its own length from a

[1] See fig. 31, p. 250, above.

single point, or from points opposite to each other in a single vertical cross-plane of the gas-vessel; we have then here for the boats or developed burden, the same succession of cases that we have already considered with the elementary load. The boat may be hung from two points anywhere in the lower semicircle of the vertical plane passing through the centre of buoyancy; or of a plane, for the reasons before stated, somewhat in advance of that point, with the same provisions for regulating the level set of the gas-vessel as were found necessary in the former case. Thus the points of suspension on the float may be at the extremities of a diameter in the horizontal plane of the axis of resistance as in fig. 67, in which case the ropes must be kept

Fig. 67.

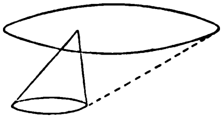


Fig. 68.

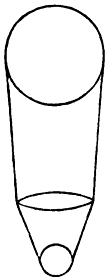


Fig. 69.

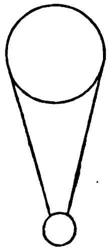
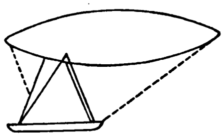


Fig. 70.

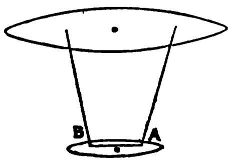


asunder with a stretcher-bar as shown in fig. 68. If the ropes are attached at any other point below the axial plane, as in fig. 69, so that the advantage of supplying the force to the gas-vessel in the axial plane of resistance is sacrificed, each pair of sling ropes lying in planes across the length of the gas-vessel may converge to the boat as shown in fig. 70. The same contrivances for keeping both gas-vessel and boat horizontal will be necessary in this case as were demanded in those last described, namely that there should be means of lengthening and shortening the suspending cords at each end.

Returning however, now to the case first instanced, that in which there are two or more points of suspension on the gas-vessel, and two or more points of attachment on the boat, let us take for simplicity the smallest number in illustration. These

points need not be placed at the extreme ends of each vessel, but for the sake of symmetry and of fair distribution of pressure at points half-way between the middle and ends of both gas-vessel and man-vessel, as in fig. 71. This is a good instance of the general form of this species of arrangement. It approximates very closely to the arrangement proposed by Sir G. Cayley,[1] to which I have before adverted; the chief differences being, that in Sir G. Cayley's figures he adds a third pair of suspending cords between the middle points of his vessels, and that in the figures given in the two latter papers referred to below, the boat is not suspended directly from the gas-vessel, but mediately from an interposed framework corresponding to the hoop of a balloon, to which his propelling agents are represented as being attached. The latter part of the apparatus does not, I conceive, answer any useful purpose,[2] and it does not at all alter, or at least simplify, the conditions necessary to be attended to in the suspension. The effect indeed is exactly the same as respects the horizontality of the gas-vessel and upper framework as it is with respect to the gas-vessel and boat in the simpler form which I have taken, with, however, this additional disadvantage,

Fig. 71.



[1] 'Phil. Mag.' vol. xlvii. p. 83; vol. 50, p. 35, Pl. 1; 'Mech. Mag.' vol. xxvi. p. 424. See p. 42, above.

[2] It must be remembered that those who propose, on account of a supposed necessity, to place the propellers on a separate frame, do not make a real insect of their craft, for the source of power is still supposed to be at work in the boat below; it is an unnatural separation of the limbs from the muscles that move them. I have before alluded to the notion adopted by many air-schemers, that all the difficulty of aërial propulsion would be solved by applying the force at the 'hoop,' or at the centre of gravity of the system (see p. 42, above). The mistake has been kept up by the neglect of persons examining this question to analyse the conditions of the problem, and the relations of all the forces concerned in the motion of the system. In fact, as I shall have occasion to show hereafter, if the force is applied at an intermediate point between the two vessels, two twisting tendencies are set up, one acting on the gas-vessel, the other on the boat, and not so as to neutralise each other.

that the cords, which in Sir G. Cayley's figure diverge to the boat, give it a tilting tendency in the opposite direction, which has also to be compensated. The ropes from the middle of the gas-vessel to the middle of the suspended burden also somewhat complicate the case. Now I have already pointed out that Sir George Cayley had omitted to show how the twisting effect of the propelling force upon the system would be got rid of, and I have mentioned the mode in which I suppose he would have endeavoured to get over it. The method there spoken of is in fact an application of the principles which I have just been endeavouring to illustrate by the other forms of air-craft. It consists in throwing the centre of gravity of the burden in front of the centre of buoyancy of the gas-vessel, by shortening up the fore suspending cord, while the hinder ropes remain of the same length, or are lengthened out. The simplest and safest way of doing this, is that of passing the cords under pulleys at A and B, and round a cylinder windlass between them. However, a similar objection applies in this case to that which rose up against the employment of the same contrivance, in the form in which only a single point of attachment was provided on the burden. If the vessels were united by more than two suspending cords, the different pairs would not be lengthened and shortened in the same proportion, and thus the load would be thrown unequally upon the different ropes in different positions, although in this case the attachments in the boat would not move in ellipses about the points of suspension in the gas-vessel. The only means of obviating this difficulty are those of having separate barrels to wind every cord upon, or of making a part of each cord of elastic material, or, finally, of having only two cords, or two pairs of cords, one on each side as in fig. 71, by adjusting which the system may be kept level. Of all these I would prefer the last plan, if I was compelled to adopt any. The maintenance of the horizontal position during flight might be further assisted by the use of a shifting ballast.

However, even with the aid of these appliances, the system of converging sling-lines would be, I fancy, but a clumsy one, and if I had no better one to offer I should not have undertaken to throw my notions into a volume, for with the exception of the low-

type examples of air-craft for solitary flying, which would not have been worth writing a book about, I do not consider any of the other modes of suspension which I have suggested as worth much in the practice of aërial navigation. However, the next species which I have to describe embodies, I believe, the true principles of construction which will render the art at once available for the service of mankind. It is the failure of the inventors of air-crafts to hit upon the device which I have now to describe which surprises me, for it will be as simple in execution as the principle on which it is founded is obvious. Nothing indeed could have prevented it from having been found out and insisted on before, but the necessity of having the converging end-stays imposed upon the inventors by the flexibility of the gas-vessel, to which they have so patiently submitted.

Now if the cords diverging from a single point of the gas-vessel (as in fig. 67) were derived by a development of that point lengthwise from two rings at a little distance from each other, so that the sling-lines were still diverging in their downward direction, no advantage would be gained—the same conditions would prevail. And the converging lines are equally inconvenient. Is there no other mode of disposing them? The mean position between the outward and the inward slope of the two cords is, of course, that of parallel lines. What then will be the result if the cords are parallel to each other? Simply this, that by this arrangement the tendency to tilting up of the ends may be entirely got rid of. There are, at any rate, these advantages to commence with, that if the cords lie in planes (as across the length of the craft) parallel to each other, there may be any number of them, and they may be of any length, without the least altering the properties of the system, geometrically considered.

In speaking hereafter of the parallel suspension I must beg to be understood as meaning, not that all the cords are parallel to each other, but that each pair of cords attached to points on the two opposite sides of the gas-vessel lie always in a plane taken at right angles to the length of the air-craft, parallel to the planes in which every other such pair is disposed. Now, as in the former

cases, this form of arrangement admits either of the cords being attached to the gas-vessel in the horizontal plane of the axis of resistance, or at points on the sides or bottom of the gas-vessel below that plane. Let us first consider the former case as being the simplest; and let us first suppose the whole air-craft flattened into a plane, and to be such a system as a parallel ruler. Let now A be the centre of gravity of the boat and B the centre of buoyancy of the float. Let B′ B″ be any number of points also

Fig. 72.

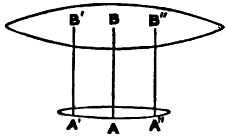
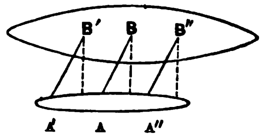


Fig. 73.



in the axis of resistance; A′ A″ any equal number of points in the boat in the same horizontal line with A; and let the distance A′ A = B′ B, A A″ = B B″, etc.; and let A B, A′ B′, A″ B″, etc. be all of the same length. Now let the system be balanced about B, so that it sits, like the beam of a well-poised balance, in a true level position; and let a horizontal force be applied to the boat in the direction A A′. I think the reader will require no demonstration to convince his mechanical instinct that the system will assume the position represented in fig. 73 without any derangement of its level.[1] For in the original position the resultant of all the vertical forces acted in the direction A B, and when the new force is added to the system, there is no tendency to throw any greater strain upon any one of the cords than upon the others; they therefore all transmit the traction equally, and the resultant of all the forces still passes through A B. The system, therefore, remains balanced horizontally about B, without the least tendency to bring either end down. Now exactly the same holds good of the air-craft floating, and free to move in any direction. Let the burden be hung by cords attached to points at the extremities of hori-

[1] A simple experiment with a parallel ruler, or with two sticks tied together by parallel cords of equal length, and balanced horizontally by suspending the upper rod by a point on the same horizontal line with the points, will convince any person of the truth of this proposition.

zontal diameters of the gas-vessel, all, therefore, in the plane of the axis of resistance, and let all these cords be brought down to the boat parallel to each other, as in figs. 72, 73, which may now be taken to represent the solid figure of the air-craft. It is clear that, since all the cords will remain parallel to each other, to whatever distance the boat is drawn forward, or pushed back, they will all alike transmit the force of traction to the gas-vessel, and will continue to apply it wholly in the axis of resistance. Again, the weight of the boat was so distributed among them originally, that the vessel was poised horizontally about the centre of buoyancy, and since the cords remain parallel, and the position of the burden with respect to each rope remains unaltered, there is no change in the conditions of balance. So that neither of the forces has any tendency to pull either end of the gas-vessel down, whatever may be the force of propulsion; and, whatever may be the relative position of the two vessels, the resultant of the forces transmitted by the suspending cords always passes through the centre of buoyancy.

Now, in this form of air-craft there will be certain conditions of construction to be attended to. The first relates to the application of the suspending cords to the gas-vessel. They are to be attached in pairs to the extremities of the horizontal diameters of the figure at any number of points in its length. At each such point wire-ropes should be passed over the roof of the gas-vessel, if necessary on strong hoops provided for their support. These ropes should be of such length as just to reach on each side down to the extremities of the horizontal diameters; to their ends strong iron rings must be attached, and each firmly tied to the body of the gas-vessel at the point where it touches it, and likewise to the rings next to it in the row of rope-ends on each side, by a cord running round the whole equator of the vessel. In these rings must be linked others forming the upper extremities of the suspending cords.

The next point to be attended to concerns the arrangement of the sling-ropes themselves. These cords must run down from the gas-vessel in vertical lines, so as not to touch its sides; and must be kept asunder by horizontal stretcher-bars or bridges, fastened between them at such distance below the gas-vessel that

they shall not be brought into contact with its lower surface, in any position which the force of traction can cause the system to assume. These bars may be made of metal tubes, as before proposed for the same purpose,[1] or of bamboos, arched and stayed, as in fig. 74, or bent and cross-braced, as in fig. 75. Or they may

Fig. 74.

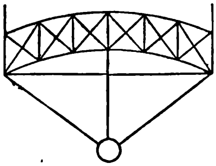
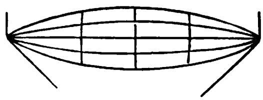


Fig. 75.



be made of metal tube curved into the form of an arch, as in fig. 76, with the boat slung from several points of its length, and the crown of the arch tied to the sling-ropes, to prevent it from being thrown out of position laterally. Again, the principle of the suspension-bridge may be applied to the maintenance of their form, as in fig. 77, where A B is a light stiff bar; C D, E F, the cords from the gas-vessel; C E, the catenary for the suspension of the bar; A C, B E, the stays by which the strain on C E is resisted by a share of the burden of the boat, which is thrown upon it by the intervention of D A, F B, the ends of the bridge-bar, which are prolonged as outriggers for this purpose. Finally,

Fig. 76.

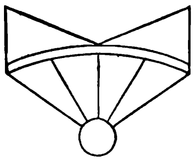
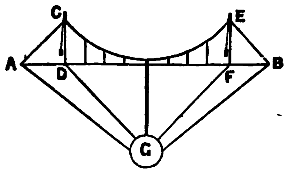


Fig. 77.



the bridge may be made of thin metal cellular tubes, on the plan of the great Welsh bridges. The craft so rigged will be represented in side elevation by figs. 72, 73, and in cross-section by fig. 68.

Of course, the longer this stretcher-bridge is, the weaker it will be. It may be reduced in length by shortening the hori-

[1] See p. 306, above.

zontal, and, of course, extending the vertical diameter of the gas-vessel,[1] so as to leave room for the required quantity and lifting power of gas. With this modification, the craft would be represented in section by fig. 78. The further the boat is hung below the bridge, and the longer, therefore, the converging limbs of the sling-ropes, the less compressing force will the bridge have to sustain.

Fig. 78.

The last point to be noticed is the attachment of the ropes to the boat. Each pair of them must be fixed to the lower vessel at points opposite to each other in a horizontal plane. I shall not here enter into particulars with respect to the exact position of this plane, as I shall return to this matter hereafter; suffice it now to remark that, in all the cases yet treated of the separate vessels, I have only considered exactly the requisites as respects the position of the points of application of the force to the gas-vessel. When I have concluded the general consideration of the suspension as respects this important member, I shall show that care is also necessary in choosing the points at which the forces shall be made to act upon the boat.

It is essentially requisite, in this species of air-craft, that the suspending cords measured from their points of suspension on the gas-vessel to their other ends at the boat should be of exactly the same length, and that the distances between the opposite ends of each two neighbouring pairs of cords should be equal, so that true parallelograms should be formed by the lines joining the four ends of any two cords on the same side of the vessels. There must be a sufficient number of sling-lines to give good support to the boat, so as not to put its stiffness to too severe a trial, by allowing weight to be thrown upon it at considerable distances from the points at which it is sustained. The boat must of course be as stiff as possible; wickerwork of rattans or of split bamboo would probably be the best material for its body. It must be strengthened with a framework of metal tubes to give support to the whole, and especially to the propelling mechanism; and it must be covered on the outside with varnished canvas.

[1] See p. 320, above.

If purposed for ordinary excursions at low speed it of course may be open above, and the passengers may enjoy the air and view as from an ordinary boat or open carriage. If, however, it be intended for the serious work of carrying the mails of England to India and New Zealand in the smallest possible number of hours, it of course must be well housed in on all sides like a covered waggon, for the protection of the occupants from the air, and its form will of course be that of least resistance. It will probably be provided with a stiff backbone of cellular metal tubes. The ropes will be fixed to rings fastened to metal ribs or hoops, which either under-gird the body of the boat, or encircle it completely. These, of course, if the boat be open above, will be properly provided with cross-ties (as in fig. 79, A B) to resist any tendency of the converging cords to wrench the opposite sides of the boat asunder.

Fig. 79.

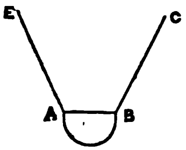
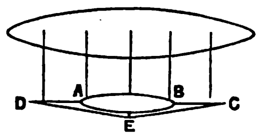


Fig. 80.



The boat must, of course, be made as long as possible, for the double purpose of eluding the resistance of the air to its motion, and of distributing its weight over as great a length of the gas-vessel as can be managed. Its length may be eked out, for the purpose of giving additional bearing to the ends of the gas-vessel, by stern- and bow-sprits of bamboo, stiff in themselves, and stayed down to the keel of the boat, as in fig. 80. There A B is the boat; B C, A D, the lengthening sprits; E C, E D, the stays; elongated canvas cones or curved capes, stretched as continuations of the boat upon these sprits as axes, will further diminish the resistance of the air to the motion of the vessel.

We now come to the species in which the boat is slung from some other points of the gas-vessel, not in the axial plane of resistance. If in the case just considered we gain, as respects the elimination of all contrivances for adjusting the level during motion, we are somewhat hampered by the complication and

greater weight of structure that is entailed upon us in other respects. If we forego the application of the suspending cords, and consequently of the force of traction in the plane of the axis of resistance, we may lead the cords at once down to the man-vessel without any intervening bridges for keeping the cords

Fig. 81.

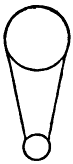


Fig. 82.

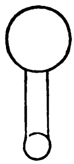


Fig. 83.

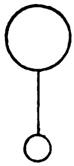
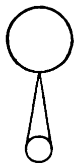


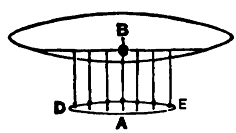
Fig. 84.



apart. Thus an air-craft constructed on the principle we are now to investigate, may present in section either of the forms in figs. 81, 82, 83, 84. We have now to provide against the tilting effect which will be set up by the traction exerted on the gas-vessel below the axis of resistance.

First, however, the craft must be put together. All the points of construction necessary to be attended to are the same, excluding the superfluous, as those detailed in the last case. Let then fig. 85 represent our vessels slung together and horizontally poised; A being the centre of gravity of the boat, B the centre of buoyancy of the float. An equal share of all the forces acting on the gas-vessel from the boat will be transmitted by each pair of cords, since they are all parallel. Let the weight be supposed to be uniformly distributed over the length of D E, and the cords to be symmetrically attached to points equidistant on either side of A.

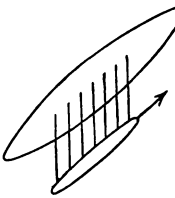
Fig. 85.



Each vertical line in the figure represents two cords, one attached on each side of the vessels. It is not of course necessary that a pair of cords should be in the cross plane of A, B, but it is convenient to represent such in the figure for illustration. The resultant then of the weight will pass in the direction of the pair A C, in the vertical plane of the two important centres. If a horizontal force is impressed on the boat in the direction A D it

will be propagated equally along all the cords; the resultant of this force will pass along the line represented by A C, and will act on the gas-vessel at C. This force therefore, as in the former analogous cases, not being met by any opposite force in the line of its action, exerts a twisting tendency, which may be measured by its moment about B. As soon then as motion ensues, the system will assume some such position as that shown in fig. 86. If the force be continued, it will derange the level until it is brought to equilibrium in a new position, by a new couple set up in the opposite direction, by the weight of the boat and the buoyancy of the gas.[1] What we have to consider then, is—how we can ballast the system in order that this resisting action shall be brought to bear so as to maintain the horizontality of the vessels. The position of the centre of gravity must of course be altered, so as to throw it so far in front of the centre of buoyancy, that its moment about that point shall be equal to the moment of the traction about the same. The amount of shifting necessary to produce this effect will be determined on the principles already established.[2] If we join B C, fig. 85, and taking B C to represent in magnitude the weight of the boat, if we draw D E horizontal, and bearing to B C the same proportion that the propelling power bears to the weight, E will be the point at which the propelling force is applied to the boat; the weight must act to enable it to counteract the torsion, and keep the vessels horizontal, for when acting at this point its moment about B will be equal to that of the traction at the

Fig. 86.

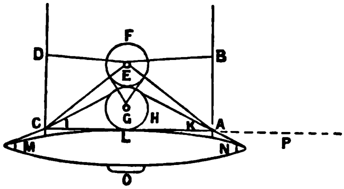


[1] If the boat had no weight, or if the propelling force were infinitely great in comparison with the weight, two results would ensue, accordingly as the former force acting through A were kept horizontal, or parallel to the length of the boat. In the first case the torsion would continue till A and B were brought to the same horizontal line, the long axes of the vessels becoming vertical, as would be represented by twisting round fig. 85 under the eye, through a right angle in the plane of the paper. In the second case the whole system would revolve about the centre of buoyancy of the gas-vessel. It is therefore, as in all these cases, the weight in the boat to which we must look for the counteraction of this tilting effect.

[2] See note, p. 291, above.

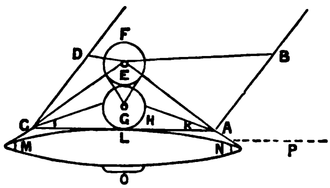
same point. This result will be obtained if the whole burden of the boat be shifted forward through a distance equal to C E, since the parallel cords will transmit the weight in their own direction to the gas-vessel. It will of course be more simply effected by sliding a small weight through a greater length, such weight being attached either to the gas-vessel or to the boat. The suspending cords themselves might be made to shift this weight to the exact point required at every velocity, by the mere change in the angle which they make with the long axis of the boat. This would be simply effected by such an apparatus as that sketched in fig. 87, where A B, C D are parts of two of the sling lines;

Fig. 87.



A, C their points of attachment to the boat; E a pulley round which is wound a cord of which the ends are tied to the sling lines at B, D; F a large light pulley wheel keyed on the same axle with E; G H another pair of pulleys large and small, coupled below E F on another axle which turns in the same upright framework I E K L, that supports E and F; G is turned by a crossed driving-band which passes round F; M, N are two pulleys at a sufficient distance

Fig. 88.



apart towards the two ends of the boat. Round H, M and N passes an endless cord, having attached to it at the point which is immediately below the axles of the pulleys, when the boat is at rest and level, a weight O, which should traverse a horizontal bar or groove. By properly adjusting the weight of O to sizes of the

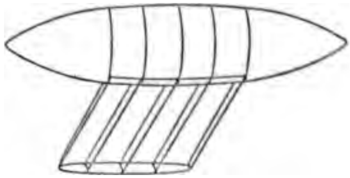
pulleys, every alteration of the angle between A B and the horizontal A P, would shift the weight, and keep the vessels horizontal. Fig. 87 represents the system at rest; fig. 88 in motion in the direction from N towards M. I shall hereafter show how this adjustment may be maintained by a self-acting apparatus, not depending on the parallelism of the cords.

It will be seen that there is no necessity in this species of air-craft, though that arrangement is the simplest, for all the points of attachment on either gas-vessel or boat to be in one horizontal plane respectively. All that is necessary is, that the vertical distance between the points of attachment of the two ends of the rope should be the same for all the cords; so that, considering each set of cords taken across the gas-vessel as lying in a plane at right angles to its length, any section of the whole craft taken parallel to its axis should be divided into a set of perfect parallelograms, by the planes of the sets of cords; in other words, the projection of every cord in the system on a vertical plane parallel to the long axis of the gas-vessel must be of exactly equal length. If any rope is attached to a point of the gas-vessel lower down than another, it must be fixed to the boat at an equal distance below the attachments of that other. The ropes may be of course of any length whatever, provided that their weight does not become too great. If fire is used as the source of power, the man-vessel will probably be slung at a considerable distance below. There may however be reasons, hereafter to be considered, which may make it desirable to be within reach of the gas-vessel by connections of moderate length. Wire rope is of course the material for suspending. That made of iron is stated by the makers to be twice as strong, weight for weight, as most other kinds of cordage. Of course for security every cord ought to be strong enough to bear nearly the whole of the burden without breaking.[1]

[1] Messrs. Newall, of Gateshead-upon-Tyne, have published a comparative table of the relative sustaining powers of hemp, and of their improved iron wire rope. From the results therein stated, it appears that their metal cordage, for every one pound of weight of material per fathom of length, will carry six hundredweight as its working load, and requires a strain of two tons to break it, and that hemp rope for the same strength requires two

Our air-craft, now properly poised and counterpoised, will be represented in motion in fig. 89. This I conceive to be the perfect type of the bipolar aerial organism. Of course in air-

Fig. 89.



craft of large size this form admits of another variation in which the hanging boat contains nothing but the motive power and the propelling agents, with the necessary attendants, while the cargo and passengers are in a vehicle forming part as it were of the gas-vessel, and in rigid connection with it, of course for stability at its bottom. In this case the power-vessel would simply represent the horses drawing a carriage, or the birds harnessed to the mythologic car. The modification in the fittings entailed by this arrangement is the same as that which has been already mentioned, in the case of the single-bodied air-craft.

We have now to consider the third or highest form of vehicle for aërial navigation, that in which the three chief functions are concentrated into three separate segments of the system. Many of the contrivers of methods of propelling gas-vessels seem to have had a notion that this was the true form of the most complete air-craft; so at least it would seem, from the proposals to which I have already alluded [1] to attach the instruments of propulsion to a frame hung between the gas-vessel and the car. I have already pointed out the inefficacy of this device as a means of preventing

pounds per fathom of the vegetal fibre. I presume these numbers were obtained by careful experiment conscientiously recorded. The proprietors of this metal rope have, at any rate, numerous testimonials to its value. And I am not aware that the similar produce of other makers, for instance of Mr. Andrew Smith, is inferior to that to which I have referred. There can be no doubt that if this cordage is valuable in any other art, it is doubly so in that of aërial navigation, where strength combined with lightness is a fundamental requisite in all the materials of construction.

[1] See p. 321.

the twisting of the system. But it is not merely to place the propeller in a particular position that I would separate the power from the burden, but to enable both to execute their special functions freely without interfering with each other. I would have three distinct vessels, one for the floatage, one for the proper burden, one for the propelling power. Now there are two methods in which this arrangement may be made. Either the power-vessel and the load-vessel may be hung separately from the float, or they may be hung the one from the other, one alone being in direct connection with the gas-vessel.

The latter arrangement may be divided into two cases; first, that in which the suspending cords are not parallel; second, that in which they are parallel. I do not think either of these modes presents any advantages, and shall therefore not say much about them.

The first sort admits of several species, of which the only form worth mentioning is that in which, as sketched in Sir G. Cayley's drawings lately referred to,[1] the suspending lines converge to the wing-frame, and thence diverge to the man-vessel below. This is a sort of development of the notion touched upon at page 318, the difference being that the power is now proposed to be applied at the point C (fig. 66), instead of at A. Without entering further into the details of such an arrangement, I may mention that, without a special contrivance for adjusting the level both of gas-vessel and of boat below, the system would have a tendency to gape, as soon as propulsion commenced, a couple being formed at first between the propelling force in the middle and the inertia of the vessels on each side of it, and that

Fig. 90.

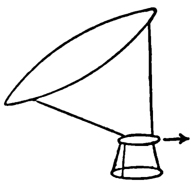
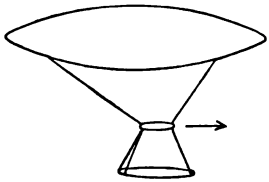


Fig. 91.



when the inertia of these bodies was overcome, and they had acquired the onward motion, the resistance of the air to their

[1] See p. 321, above.

heads would maintain the distortion. So that if their suspending lines were symmetrical as in fig. 64, when motion ensued, the stern of the gas-vessel would be drawn down, and that of the man-vessel up, so that the system would assume some such yawning shape as that represented in fig. 90.[1] It would be necessary to shorten up the fore cords of each vessel, and to let out the hinder ones, as in fig. 91.

No such complication of adjustments is necessary in the cases in which the cords are parallel. In air-craft of this next species it would make no difference in this respect, whether the power vessel were between the other two, or at the bottom of the system. The relative positions of the vessels would be different during flight, as represented in figs. 92, 93. No other contri-

Fig. 92.

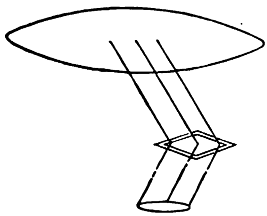
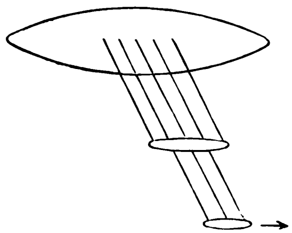


Fig. 93.



vances for the maintenance of the level would be required in these cases, than the arrangements which have been already spoken of as requisite for the two-bodied craft with parallel suspension. Of course the vessels for carrying the passive load may be multiplied to any extent; a chain of them may be hung one below the other. But this arrangement would confer no advantage, and would only be a descent in the scale of development, by

[1] I should here repeat, in justice to Sir G. Cayley, that this derangement would be but small in such service as that which he contemplated for his air-craft, namely, the attainment of a rate of motion not exceeding fourteen miles per hour, with a resistance to be overcome bearing to the burden a ratio of 1065 : 66237, or of 1 : 63·13 (See 'Mech. Mag.' vol. xxvi. p. 423, and p. 42, above). But in seeking to prepare the way for the future voyagers of the air, we must not only provide for the possibility of far higher speeds than this, but for the exertion of powers of propulsion far greater in proportion to the weight sustained.

the introduction of mere 'vegetative repetitions' of similar organs. The concentration of function is complete with the ternary division.

The other genus of the class of three-bodied air-craft is that in which both of the two smaller vessels are directly suspended from the float. This admits of two divisions: the first, that in which the power-vessel is above the man-vessel; the second, that in which the latter is the upper of the two. Further, either of the boats may be suspended from the float by cords, diverging, parallel, or converging; and the power may be so hung as to apply its force to the rest of the system, directly in the plane of no twisting, or below it. The various combinations of these possibilities will furnish thirty-six several species of designable air-craft. Far be it from me to describe or even to mention them all. Suffice it to make the following remarks:—I have already stated above that the system of parallel suspension is the only one of any great value for the service of the power-vessel. But as respects the man-boat, its level will be perfectly secured if the gas-vessel from which it is slung is kept horizontal. Of itself the passive burden will not have the deranging tendency, which in the case of the power-boat the parallel cords are calculated to obviate, so that this arrangement will not confer upon the former the advantage which the latter derives from its adoption. On the other hand the method of converging sling-lines will, in the case of the separate burden-boat, serve a peculiar end, which I shall presently point out, and which neither the parallel nor the diverging cords will secure. I shall therefore consider only that subgenus of air-craft which may be described as having the sling-lines of the man-vessel converging, and those of the power-vessel parallel. There are four forms included under this head, thus: man-boat above, power below; and power above, man-boat below; first power hung from plane of resistance; second power hung from points below that plane; third power hung from plane of resistance; fourth power hung from points below that plane. No difference in principle is involved in the difference of form. I shall therefore first consider generally the conditions to be attended to in the four cases.

There will be two sets of sling-ropes attached to the gas-

vessel; these must, of course, be so arranged as not to interfere with each other. For those by which the power-boat is suspended will have to alter their position when motion commences, and must therefore be so placed as not to come in contact with the ropes of the other boat, when the angle of inclination is altered. The centre of gravity of the burden-vessel will, of course, lie directly under the centre of gravity of the float. Now with this mode of suspending the load, namely, that by converging cords, two objects are secured. Firstly, by this means all the stability of position, when not propelled from the boat so hung, which, as was before acknowledged, belongs peculiarly to the old eggoon with its short boat hanging below it,[1] is obtained. For thus the centre of gravity of the system may be placed as low down as may be desired; and, as in the case of the balance-beam, the further the centre of gravity lies below the point on which the system is poised, the less is the disturbance of level produced by any given force tending to derange it. With the usual form of attempted air-craft with only two bodies, the very arrangement which secured the stability was fatal to the speed of propulsion. But with the addition, as in the forms here suggested, of a third movable vessel for the traction of the system, both stability in the horizontal position and rapid locomotion are—if the power is found—provided for. Secondly, the cords converging to the burden-boat from the parts of the gas-vessel towards its ends will act the part of the stays, spoken of in a former chapter as useful for helping to prevent the tendency of the head and tail of the float to turn up.[2] Thus the burden itself, being kept away from the body of the gas-vessel by its whole weight, will answer the same purpose as a sprit or mast of prodigious strength, fastened vertically to the lower part of the gas-vessel, and giving support to the stays or tie-ropes. It is equivalent, indeed, to a mast quite unbreakable, and of strength sufficient to bear the whole weight of the load without bending.

We will now proceed to consider the four forms in which this three-bodied arrangement may appear. These are represented in side elevation and in section in the diagrams, figs. 94, 95, 96,

[1] See p. 137, above. [2] See p. 250, above.

97, 98, 99, 100, 101, in the order in which they were before specified. In each figure B marks the burden-boat, P the power-boat. In each of the side-views the system is supposed to be in motion under the traction of the propelling power. The first species (figs. 94, 95) is that in which the passive load-boat is the uppermost of the two, that containing the propelling power being hung by cords attached to the gas-vessel at the horizontal plane passing through the axis of resistance. In this case the whole of the sling-lines belonging to the burden-boat are entirely enclosed between those of the power-vessel. Either set, therefore, may be attached at any points in their proper planes, on the length of the gas-vessel. For the burden-lines can never interfere with

Fig. 94.

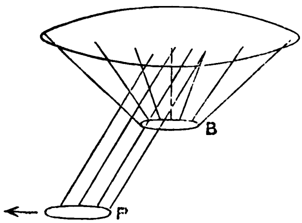
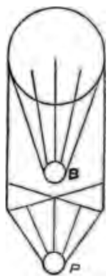


Fig. 95.



the to-and-fro motions of the power-lines, which, of course, are confined to planes parallel to that passing vertically through the long axes of the vessels. The sling-lines of the power-vessel will of course require to be stayed out by stretcher-bridges, to keep them clear not only of the sides of the gas-vessel, but also of the interior ropes just mentioned. Both sets of cords may be of any length, provided always that the power-lines are so much longer than the others that their boat shall hang so far below the burden-vessel as to be clear of it in every position, and for stability the longer the burden-cords are the better.

The second form (figs. 96, 97) is the same as the last, except that the power-boat is hung from points of the gas-vessel below the plane of resistance. These points cannot, of course, be very low down on the sides of the float, for in that case their directions would pass through the burden-boat, or at any rate would be

hampered by its converging sling-lines. To prevent the two sets of cords from interfering with each other, those belonging to the power-vessel must be as long as can be permitted by other con-

Fig. 96.

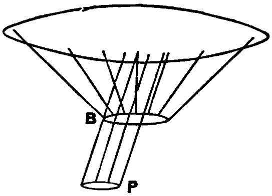
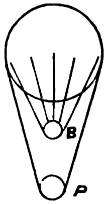


Fig. 97.



siderations of convenience, and the burden-boat must be slung nearer to the float than would be desirable if this limitation did not occur. The points, too, of attachment of the two rows of ropes to the float must be so chosen that the motions of the parallel set are not interfered with by the others.

The third species (figs. 98, 99) is that in which the power-boat is hung between the gas- and the burden-vessel, the power being hung from the plane of resistance. In this case it is clear that there must be no ropes running down to the burden from the middle parts of the gas-vessel to which the other boat is hung; for any such lines would interfere with the motion of the parallel harness of the power-vessel. The latter must of

Fig. 98.

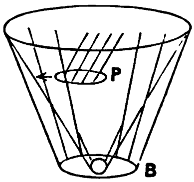
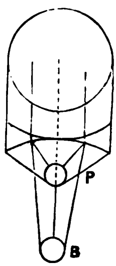


Fig. 99.



course be hung up as high as possible, to keep it clear of the burden-lines. And the main load must be as low as can be managed for aiding the same end, as well as for enhancing the stability of the level.

In the fourth species—the last (and the patient reader will rejoice with me) of the air-craft that I shall have to describe—the power, being again above the burden, is slung to points below the axial plane of resistance. In this case the burden may be suspended from points all along the length of the gas-vessel, for the power-boat and its sling lines may be included entirely within them. The indications are that the burden-boat should be as low as possible, for the same purposes as in the last case,

Fig. 100.

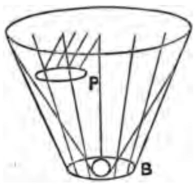
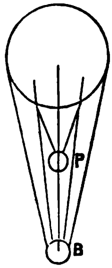


Fig. 101.



and for the additional end of throwing the points of suspension about the middle of the gas-vessel, as near as may be to the extremities of its horizontal diameters. On the other hand the sling-lines of the power-boat should be attached as low down as possible, and may even be reduced to a single row attached along the middle line of the bottom of the gas-vessel, as in fig. 76.

Now all these forms would, I believe, work; the most promising, however, I take to be the second and the fourth (figs. 96, 97, 100, 101), each of which have their special advantages—the former that the power-boat, containing perhaps fire, is far from the gas; the latter that the centre of gravity is low down.

Concerning the construction of each of these kinds of air-craft but little remains to be said here. As respects the suspension of the power-boat, all that was said before, about the boat of the two-bodied air-craft, with parallel cords, applies to this important part of our present system. The burden will of course be suspended by wire-rope. The chief part of its weight should be borne by the cords nearest to the middle part of the gas-vessel; the length of these should be unalterably fixed. The flat rope

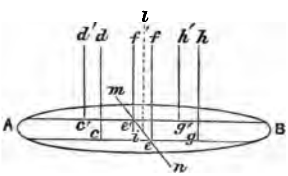
will be useful for this side rigging, as offering less resistance to the air edgeways than the round cord, which will be better for the end-stays. Those towards the head and stern may be fitted with an arrangement for tightening or slackening them a little, so as to adjust the horizontal set of the ends of the float. The burden-boat will of course be properly formed for eluding the resistance of the air, in the same manner as the power-vessel.

It will be seen that, in the kinds of air-craft just described, the burden, forming virtually, together with the gas-vessel, a single system, rigid as respects all the forces which we have now to consider, a system too of which the centre of gravity is placed far below the long axis of the gas-vessel, the conditions as respects inertia of the mass drawn after it by the power-boat are different from those of the simple gas-float, submitted to the traction of a vessel containing all the load as well as the propellers. Therefore, in the cases of the first and third of our last four species (in which we endeavour to apply the force directly from the traction-boat to the rest of the system, in such a manner that the whole shall be at once propelled straightforwards, without the need of any additional contrivance for maintaining the level), we must take account of this difference, and provide accordingly. The plane then, in which the points of suspension on the gas-vessel must be arranged, must be so far below the horizontal plane passing through the axis of resistance of the gas-vessel, that the twisting tendency due to the inertia of the mass below it, shall be counterbalanced by that of the excess of resistance above.

In all the different forms of air-craft which I have enumerated, I have endeavoured to show how they must be arranged so that the mode in which the propelling force acts upon the gas-vessel shall not involve any derangement of the horizontal set of the system. This however is not all that is necessary to be provided against. It is requisite that the force, as it acts upon the power-vessel to which it is primarily applied, should not have any tendency to throw that part of the system out of level; for if this occurs, one of two results will follow, according to the manner in which the source of power is suspended. Now the modes of suspension may be divided into two sorts, first, that in which

the power-boat is poised about an axis passing through its own body; second, that in which it is balanced about an axis in the gas-vessel, or somewhere else above and beyond its own mass. In the second case the propelling force will have no tendency to twist the boat about itself, though it may derange its position with respect to the rest of the system; and this fault has already been provided against. So that with this manner of arrangement, the point in the boat at which the power acts upon it is of comparatively little importance, provided its proper direction is strictly maintained. If, however, the propeller-body hangs like the flyer-man of our elementary two-bodied air-craft, by a single point or cross-axis in its own part of the organism, it is clear that, unless the force is properly applied, it will twist the lower body about itself, and so waste a large amount of power, although it may transmit to the gas-vessel above without further deduction all of it that becomes actually available for propulsion below. Again, in the cases in which the power-vessel is hung from the float by cords lying in parallel cross-planes, the axis of the gas-vessel always remains parallel to the axis of the power-boat, so that unless the latter is kept horizontal, the former, notwithstanding the proper arrangement of the traction cords, will be thrown out of its level set. Now the boat thus hanging by parallel cords from the float is in exactly the same condition as respects balance as if it was poised upon an axis within its own body, namely on an axis passing at right angles to the length of the boat, through the point of intersection of the resultant of the lines of tension of the sling-ropes with the plane in which their ends are attached to the boat. Thus in fig. 102, A B being a boat (supposed transparent) slung by parallel cords, $c\ d\ c'\ d'$, $e\ f\ e'\ f'$, $g\ h\ g'\ h'$, from a gas-vessel above, let $i\ l$ be the direction of the resultant of the tension of the cords, $c\ e\ g\ c'\ e'\ g'$ the plane (parallel to the axis of the boat), in which the ends of the cords are attached to the boat, i the point of intersection of $i\ l$ with the plane. Let $m\ n$ be a line drawn in the plane $c\ g'$ through the point i, at right

Fig. 102.



angles to any line parallel to the axis of the boat. I think it will be quite evident without demonstration that the boat is virtually poised about the line $e' i e$ as axis. The more important case then of the boat hung by parallel cords will include, as respects the conditions of balance, that of the propelling power suspended directly by a single point or axis of its own body. The only difference being that in the former case, which I shall examine specially, if the power-boat is turned about its axis, the gas-vessel is so likewise, but in the latter case the flyer may revolve without any change in the position of the float.

Now first, considering the system as at rest and free from any horizontal force, its balance may be one either of stable or of unstable equilibrium. It will be unstable only in the case in which the upper ends of all the cords are attached to the gas-vessel in a plane passing through its centre of buoyancy, and parallel to the plane $c\,g'$, and in which also the centre of gravity of the boat lies at or above the point i.

If either the centre of buoyancy of the gas-vessel is above the plane of the upper ends of the cords (and it cannot be below it by reason of the form and construction of the craft), or the centre of gravity of the boat below the point i, the equilibrium will be stable. Since, however, we desire in some cases to get the upper ends of the sling-lines as high as possible, it is better to consider the stability as depending on the position of the centre of gravity of the boat. Now the boat may be likened to a balance-beam, the further its centre of gravity below i, the more stable will be the equilibrium in a horizontal position. The requisite is then, that the centre of gravity of the boat should be low, and the plane of the joints at which the sling-lines are attached to it high up. I have here been anticipating a part of the matter due to my next chapter, but it is necessary here first to understand where the centre of gravity of the boat is to be.

The question now is—How is the propelling force to be applied to the boat-sling by parallel cords, so that it shall not derange the level of the latter? Now there are two ways of managing this, just as in the case of the gas-vessel. Either the force may be applied so that there should be no tendency to twist the vessel, or so that it shall give rise to a counter-force

tending to turn the boat in the opposite direction, so as to compensate the former torsion in the position of the required level.

Now we have two cases to consider; Firstly, the sling-ropes may be attached to the gas-vessel in such a manner as that no tendency to turn the system round in a vertical plane shall be set up by that part of the apparatus. Secondly, they may be attached below the plane of resistance, and therefore there may be such a tendency. We will first take the former case, in which the boat is suspended from points in the plane of the axis of resistance. In this case, that there may be no derangement of the level, the moments of the forces of gravity and of propulsion about the axis of balance must be equal and opposite. If now both of these forces act directly in planes passing through this axis, the moments of each about it are nothing, and therefore the condition is satisfied. Again, if either of them act directly in a plane passing through it, the other must likewise: that is, if the centre of gravity is to remain directly beneath the axis in a vertical line, the propulsion must act upon the boat in the horizontal plane passing through it—in other words, the propellers on each side must be articulated to the boat in the same horizontal plane in which the sling-lines are attached—and *vice versâ*. But if the propellers act upon the boat either above or below the plane of the suspension joints, the position of the centre of gravity of the boat must be changed, so as to make its moment about the axis of balance equal and opposite to that of the propulsion. If their point of action is above, the centre of gravity must be shifted backwards, if below, forwards.

In the second case, in which the propeller body is hung from points below the plane of resistance in the gas-vessel, the force is applied to the latter part of the system, so as to have a deranging tendency, which, as has been already shown, is to be neutralised by an adjustment of the centre of gravity; therefore the same mode of compensation will suffice for the two disturbing influences, both for that due to the action of the forces on the boat, and that arising from the manner of their transmission to the gas-vessel. But these two twisting agencies may coincide in direction, or may be opposed to each other; if the former be their relation, the correction must be equivalent to their sum, if the

latter, to their difference. Now the question arises, May not the two twisting tendencies be made to neutralise each other, so that, their difference vanishing, there may be no necessity for any further compensation? or at least, that the amount of shifting of the centre of gravity requisite to maintain the level may be reduced to within a very small compass.

The tendency, if any, arising from the position of the points of suspension on the float, is always to turn up the heads of the vessels; that due to the place of the propellers in the boat assists this, if they are articulated below the axis of balance, and is opposed to it if they are above. The following three cases will illustrate the relations of these tendencies In figs. 103, 104, 105, B represents the centre of buoyancy of the gas-vessel; the straight arrow marked P shows the line of action of the propellers; and the straight arrow marked W the direction of the resultant of the weight of the boat, vertical through its centre of gravity. The curved arrows in figs. 104, 105, indicate the directions of the tendency of torsion in each member of the system. In fig. 103 the force, P, is applied to the boat in the horizontal plane, *c e g*, passing through the axis of balance, and is transmitted to the gas-vessel in the horizontal plane, *h k*, passing through the axis of resistance. There is no tendency in this case to twisting in

Fig. 103.

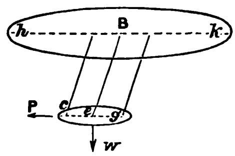


Fig. 104.

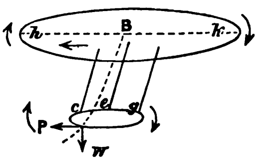
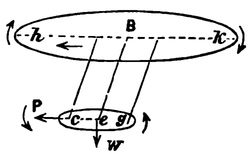


Fig. 105.



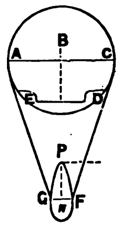
either direction, and the centre of gravity need not be shifted at all when motion commences. In fig. 104, P acts below the axis of balance of the boat, and below the plane of resistance in the float, so that there is a double tendency to turn up the heads of the vessels; and this has to be compensated by a double shifting

forward of the centre of gravity, as indicated in the diagram. In fig. 105, P acts above the axis of balance of the boat, and so tends to turn its head down, but the traction works upon the float below the plane; *h k*, and so tends to turn up its head. Now the heads of the two vessels cannot turn towards opposite directions in a vertical plane; they must therefore both obey the more powerful of the two opposing forces. The problem then becomes, to make the two as nearly equal as possible, so as to reduce the distance through which the centre of gravity has to be moved to the least possible. If this can be reduced to nothing, the system is as perfectly independent of adjustment as is the arrangement of fig. 103. Let us call the propelling force P, the axis of balance of the boat *e*, and the centre of buoyancy of the float B. Now the measure of the downward tilting tendency of the head is the moment of P about *e*, and of its upward tendency the moment of P[1] about B; and the object is to keep the moments of the weight of the boat about *e*, and of the weight of the whole system about B, each nothing, and yet to maintain the level. The conditions then are, obviously, that the moment of P about *e* shall be equal, and opposite to its moment about B. That is to say, the propellers should be articulated to the boat in a horizontal plane, which is as far perpendicularly above the plane in which the sling-ropes are attached to the boat, as the plane in which the upper ends of the ropes are attached to the gas-vessel, is below its centre of buoyancy. Now the vertical diameter of the boat must be very small, compared to the same diameter of the gas-vessel; there is therefore but little room for increasing the distance of the propellers above the axis of balance of the boat, especially since it must be remembered that this axis cannot be very low down in the boat, because, for the sake of stability, it must be at a considerable distance above the centre of gravity. The indication is, therefore, to place the points of suspension on the gas-vessel as high up as may be convenient, to elongate the vertical diameter of the boat, to attach the lower ends of the cords to the latter vessel at about the middle of its height, to

[1] More truly of P + R; R being the resistance of the air to the motion of the boat. But since this will be small in comparison of the other forces, I have here neglected to consider it.

articulate the propellers to the boat as near to its top as possible, and to place the greater part of the weight of its burden as near as possible to its bottom. This is illustrated by fig. 106, which represents the cross-section of a two-bodied air-craft with parallel suspension, of the species sketched in fig. 89. A C is the horizontal diameter of the gas-vessel; B its centre of buoyancy; D E, the points of suspension on the gas-vessel; F G, those on the boat; P, the point of application of the propelling force; W, the place of the centre of gravity of the boat. With such an arrangement as this, the necessity for compensation by shifting the centre of gravity may be reduced to a minimum. And, of course, the same method applies to the three-bodied craft in which the power-boat is similarly slung. It must, however, be observed that though the axis of balance of the boat is fixed, the centre of buoyancy of the gas-vessel is not, and will be subjected to changes of position with the expansion of the gas. The greater the bulk of the gas, the lower of course its centre of gravity—that is, the centre of buoyancy of the float—will be brought, but not in direct proportion to the increase of bulk. This change will necessitate slight adjustments of the position of the centre of gravity of the burden, as the height in the air at which the system is moving varies.

Fig. 106.



We have now, I think, sufficiently provided, in putting together the vessels of our craft, that the propelling force, when it comes to be applied, shall not derange the level set of the system.

Before quitting the subject of suspension, I must take leave to add a few words in this place on a point which, though not a branch of aërial navigation, is a particular case of the propulsion of gas-vessels. I have already had occasion to mention the possibility of using the buoyancy of light gas as a means of assisting locomotion upon land.[1] It may be interesting to enquire briefly whether it may be possible to render the principle of the neutralisation of weight by floatage serviceable, in assisting us to obtain speed in the other sorts of locomotion on the solid or the

[1] See p. 32, above.

liquid surface of the earth. The subject comes properly under consideration here, for it involves all the conditions of aerial travelling of which I have yet attempted the solution, and none of those which are to follow. It must depend, too, particularly for success upon the mode of suspension which might be adopted, in attempting to carry it into practice.

Attempts have been made already to ally the powers of the air to the art of travelling upon land. Matter for amusement on this head may be found in Bishop Wilkins's chapter, 'Of a Sailing Chariot, that may without Horses be driven on the Land by the Wind;'[1] wherein he not only gives accounts of instances in which carriages have been propelled by the traction of sails urged by the wind, like the ice-boats of Canada at the present day, but suggests that the effect might be more conveniently obtained by making the wind turn a set of vane-sails which should drive the wheels. The curious reader, too, will meet with entertainment from the kites and char-volant of quaint, pedantic George Pocock, sometime of Bristol, schoolmaster.[2] These fancies, however, are not, though aerial, connected with the use of buoyant gas. But balloon railways of different kinds have been proposed. One inventor gravely undertakes to support on balloons lines of railway laid through the air from Dover to Calais, on which locomotive engines and trains shall travel as on the iron network of England. A model of such a scheme was to be seen in the Exhibition in Hyde Park. Others propose to relieve the carriages, which are to run on fixed lines, of their weight by balloons, so that they may be more easily propelled.[3] This notion, impracticable to the very last degree, is, however, connected in principle with the point which I am about to discuss. In the same manner it has been proposed to marry the balloon to the sea-boat, so that the keel of the latter just resting on the water shall glide over its surface, taking its

[1] Wilkins, 'Math. Mag.' Dædalus, c. 2.

[2] 'The Aeropleustic Art, or Navigation in the Air by the Use of Kites or Buoyant Sails,' 4to. 1827. The title is a misnomer—there is not a word in the book on navigation in the air. Its subject is the traction of wheel carriages on land by kites.

[3] 'Mech. Mag.' vol. xxvii. p. 249; vol. l. p. 142; and vol. li. p. 142; 'Aerost. Mag.' p. 79; M'Sweeny, 'Aer. Nav.' p. 71.

propelling purchase from the dense liquid.[1] Again, it has been proposed to make buoyant gas do the work of masts in lifting, not the ship itself, but its sails, so as to keep them open to the wind.[2] The latter expedient would require the aid of the wind: to the other notions of making gas-floats auxiliary to locomotion on land or water, the wind would be fatal.

I shall not consider whether it would be worth while, under any circumstances, to use buoyant gas-vessels systematically for diminishing the burden of heavy bodies, intended to be transported rapidly over great distances across water or land. The question in all these cases, supposing the air to be still, is whether the resistance of the air to the gas-vessel will be less than the resistance of the water to the part of the boat immersed in it, or than that due to the friction of the wheels of the carriages, and to the necessary lifting of the moving mass over unevennesses in the road. If the sea were smooth, there would be no necessity for such a floated boat being immersed in it at all; its propellers only need dip into the water. But in any case there would still be the difficulty arising from the action of the wind on the gas-vessel, a disturbing force which would be fully as injurious to the progress of the system if it was impressed sideways, as if it met the vehicle with direct opposition. We may be able to find our currents in the air aloft, but certainly cannot ensure a favourable breeze below. I shall therefore consider only the question of the possibility of accelerated transit, on a plan which might serve as an occasional expedient or as an amusement, when the wind might be propitious. And I shall take it in the simplest form of all possible human locomotion, that of the man upon his legs, leaving it to the reader if he should feel inclined to wing with gas-float horse, cab, velocipede, or funny, and to make experiment of the result.

If the weight of a man is neutralised by any contrivance, much less force is required to move him than if the burden of his body has to be lifted continually by the moving power. Two appliances are in common use for this purpose in locomotion

[1] M'Sweeny, 'Aer. Nav.' p. 46.
[2] 'Mech. Mag.' vol. l. p. 262.

upon solid surfaces, wheels and skates. The force applied to the movement of a person supported on either of these forms of instrument would be, of course, if the road or the ice were quite smooth and hard, as completely relieved of the resistance due to his weight as if he were suspended and counterpoised on a beam balanced on a point—so long as the line of action of the force is strictly confined to a horizontal plane. But neither macadamised granite, iron rails, or ice, ever present either of these qualities in perfection: the weight of the body has to be lifted continually over obstacles, or to bend the surface that bears it into a depression at the point of contact. Besides which there is in both cases, as well as with the balance beam, considerable friction to be overcome. Again, not the slightest rise out of the plane of level can take place, even if the surface of support be inclined at the exact angle of motion, without a part of the weight having to be lifted by the propelling force, which, if any attempt be made to leave the plane of support, must bear the whole load of the system. If, however, the weight of the body be counterpoised by a buoyant float, the conditions are quite changed. The system is free to move in every direction without any friction, and without any of the weight being thrown upon the moving force. The only impediments to rapid motion are the inertia of the whole system, including, of course, that of the gas-vessel and its contents, and the resistance of the air to the large body immersed in it. The inertia is but a transient resistance, and repays the whole of the force expended in overcoming it, by sustaining the motion afterwards. The resistance of the air, then, is the only opponent to be combated.

The question, then, as applied to the case of a man upon his legs is this—Is the force required to propel through the air at a given speed a gas-vessel just capable of sustaining the weight of a man, less than the force required for him to progress at the same pace without it? Or,—Given the force put forth by a man in locomotion on the ground in the usual manner, can he attain a greater speed by the same exertion, if his weight be counterpoised by a buoyant float, notwithstanding the resistance of the air to the latter? The latter form of the question I shall take as the most convenient.

I have shown before[1] that in walking a yard, a man of the average height raises the weight of his body (150 pounds) to a height of three inches. And this is equivalent to raising 12·5 pounds through a yard.[2] For every yard, then, that he walks he overcomes a constant resistance, equal to 12·5 pounds, and independent of the velocity of his motion. In walking, then, at any pace which he can continue for a considerable time without distress, a man may be considered as exerting a uniform force of this amount, and just balanced by the resistance to his motion. The rate of four miles per hour is a convenient speed for a pedestrian; at this pace, then, he may be considered as exerting a force equal to a pressure of 12·5 pounds. This, then, is the measure of the force of his legs in easy work.

His weight now is to be counterpoised. According to the table which I give below,[3] 2,192 cubic feet of hydrogen are requisite to sustain 150 lbs. The dimensions of a gas-vessel of our provisional form and with such contents must be 8·87 feet in diameter, by 53·22 feet in length. The extent of surface of the envelope will be about 1,140 square feet; and if made of varnished silk, weighing ·05 lbs. per square foot, will (see Appendix B) weigh 57 pounds; to this must be added the weight of the framework for stiffening the gas-vessel, and that of the suspending cords; this may add another 100 lbs. to the burden. Now, to get this weight supported, we will suppose the greatest diameter of the vessel to be 9 feet exactly, and the length of it to be increased by inserting a cylinder in its middle (diminishing thereby the resistance it will suffer from the air) of sufficient length to counterpoise both the excess of weight already reckoned, and the load of the additional envelope. The length of the piece thus let in may be taken at about 106 feet.[4] This will

[1] See p. 26, above. [2] 3 inches $= \frac{1}{12}$ yard; $\frac{150}{12} = 12{\cdot}5$.

[3] See Appendix F.

[4] The area of a circle 9 feet in diameter is 63·61 square, and its circumference 28·27 linear feet. So that the cubic contents of every foot in length of the required cylinder are 63·61 cubic feet, and its surface 27·28 square feet. Now a cubic foot of hydrogen should lift ·0684 lbs. avoird. (see Appendix F. Each foot in length then of our interpolated cylinder will sustain a weight of $63{\cdot}61 \times {\cdot}0684 = 4{\cdot}35$ lbs. And its surface of oiled silk

make the whole length of the float, $106+53\cdot22=159\cdot22$, say 160 feet. The proportion, then, of the greatest breadth to the length of the figure will be $\frac{9}{160}=\frac{1}{18\cdot9}$; not an absurd form for the purpose of cleaving its way through the air, as may be conceived from the outline, fig. 107, which represents it.

Fig. 107.

The next question now is generally—What is the resistance of the air to such a body, moving in the direction of its length, with the blunter end forwards, at given velocities? Or, specially,—What velocity can be given to it under such conditions by the force exerted by a man in ordinary walking? This is a question, for answering which, as I have already shown at length, we have no sufficient data. Let us, however, seek an approximation.

The area of a circle of 9 feet diameter is $63\cdot61$ square feet. Now according to the experiments of Rouse, as stated by Smeaton,[1] the resistance of the air to a square foot of surface of a flat plate moving parallel to itself at the rate of one mile per hour is $\cdot005$ pound. And the fluid resistance increases as the square of the velocity. The resistance, then, to a mere plane of the area of the cross-section of our gas-vessel, if propelled at the rate of 1 mile per hour would be $63\cdot61\times\cdot005=\cdot31805$ pounds. Now we have for the propulsion of our vessel a force equal to a pressure of $12\cdot5$ pounds.[2] First let us suppose

will weigh $28\cdot27\times\cdot05=1\cdot42$ lbs. per foot of length But the additional envelope will require a certain weight of framework to support it. What the weight of this would be I am not in a condition to state. I will assume however that the weight of the canes and cords necessary for the construction is equal to the weight of the silk; this then will make the weight $2\times1\cdot42=2\cdot84$ lbs. This will leave a residual buoyancy of $4\cdot35-2\cdot84=1\cdot51$ lbs. per foot in length of the cylinder. Now we have $(57+100$ say$)$ 160 lbs. more to be lifted; this then will require to be inserted $\frac{160}{1\cdot51}=106$ feet in length of such a cylinder. The whole weight then of the gas-vessel will be $160+(106\times2\cdot84)=461\cdot04$, say 460 lbs., no slight weight for a float,—but, yet, a float.

[1] 'Phil. Trans.' vol. li. Part I. p. 165.

[2] See p. 351, above.

the resistance to our bolt-shaped figure to be no less than that offered to its cross-section. We find the velocity, expressed in hour-miles (x), with which our pedestrian will move it by the following proportion—

$$\cdot 31805 : 12\cdot 5 :: 1 : x.^2$$

Hence $x = \sqrt{12\cdot 5 \div \cdot 31805} = 6\cdot 27$ miles per hour. Here, then, would be a gain of two miles and a quarter per hour in pace for the walker at four miles; but how much greater than this his actual advantage would be we have no data for determining. Hutton showed that the resistance of the air to a sphere was about $\frac{1}{2\cdot 4}$ of that to a circular disc of the same diameter. And Sir G. Cayley found that the resistance to a prolate spheroid whose major axis was three times the length of its minor was $\frac{1}{4\cdot 8}$ of that to a circular plate of which the diameter was the minor axis of the spheroid.[1] There can be no doubt that by increasing the length to so great an extent as in the figure I have proposed, the resistance would be reduced to a much smaller amount. Let us assume that it is brought down to a tenth of that due to its cross-section; though there can be little doubt that the diminution would be far greater in reality. The resistance at 1 mile per hour would be ·031805 lb. The speed, then, at which the resistance would become 12·5 lbs., supposing the ratio of increase still to be as the square of the velocity, would be, $x = \sqrt{12\cdot 5 \div \cdot 031805} = 19\cdot 8243$ (20 nearly) miles per hour—a pretty good pace for a pedestrian along the road.

I conclude, then, that for some purposes, such as pedestrian tours in fine weather, or for the use of couriers in countries ill supplied with railways, this mode of transit might be useful. I can conceive no more delightful or elegant kind of travelling than that of skimming over the earth in tiptoe fashion with this apparatus—the perfect realisation of the seven-league boots of the fairy tales. Of course the runner must be attached to his float in such a manner that his power shall all be available in the

[1] 'Mech. Mag.' vol. xxvi. p. 423.

direct forward sense, not being wasted in taking great upward bounds into the air. For this purpose it is necessary that he must be suspended so that in striking his leg directly out—by the action which would amount to a kick downwards if he was hung with the axis of his body vertical—the effort should meet with full resistance in the line of progress, or in a direction making but a very small angle with the horizontal, so as just to give sufficient elevation to the curve of each bound to carry the body clear of the ground. The system will, of course, have a slight preponderance of weight, to ensure the feet coming down to the surface at the end of each stride. The angle of impulse will, of course, be determined by the mode in which the man's body is slung by the cords. The runner must have means of shifting the angle at which he is suspended for the purpose of

Fig. 108.

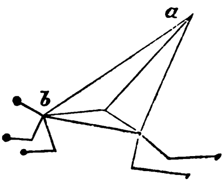


Fig. 109.

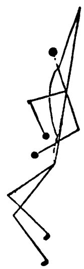
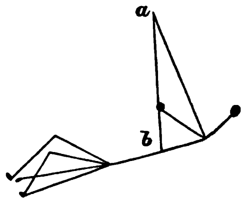


Fig. 110.



altering his mode of progression, to enable him on occasion to bound vertically to great heights, to leap over houses, trees, and other obstacles, and most especially to enable him to stop himself at will. For unless he could throw his body into such a position as to check gradually the momentum of the huge body, weighing nearly four hundred pounds, which he would have carrying him away at the velocity which he had given to it, he would be quite helpless when once in motion. It will be necessary, then, that he should have means of shifting the inclination of his body at will, and that generally when progressing he should be hung with his body inclined to the vertical at a very considerable angle. We need not here consider the mode in which the gas-vessel is to be kept horizontal; this may be effected by any of

the modes of attachment of the lines which were described above for the flyer's float. The inclination of the man's body may, of course, as in the case of the flyer, be altered by means of a shifting weight. It may also be effected by the adjustment of some shifting braces, as shown in figs. 108, 109, 110, which represent the runner respectively in the action of rapid forward motion, of springing upwards, and of stopping himself. The different positions will be obtained by shortening up the fore braces, *a b*, which, attached permanently to the main sling-line at *a*, pass down over each shoulder through hooks, from which they may be released at will (as in fig. 109), and are buckled to each side of the lower part of the chest. Each step will, of course, be a spring taken probably by each leg alternately. During each stride or bound the legs will be drawn up, so that when the toe touches the ground, the leg by being suddenly struck out and straightened will produce the impulse. Of course, so long as the leg is straight and the toe touching the ground, neither will the body descend any further, since its weight is supported by the float, nor can any force be exerted on the ground. In endeavouring to ascertain the speed that the runner may attain, I have tacitly assumed that the mode in which the force would be put forth in the new mode of progression, namely, that of sharp jerks given at intervals considerably longer than those of the steps in walking, would not be less convenient to the muscles than the slow and steady movement of walking. It doubtless would be more fatiguing to some persons than walking, but practice would probably render it quite as easy a mode of supplying force as the ordinary exercise.

CHAPTER IX.

CONDITION 7.—THE VESSELS MUST BE ABLE TO KEEP A LEVEL POSITION WHEN FLOATING FREELY.

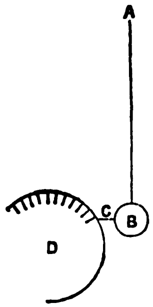
Our air-craft is now put together, and this in such a manner that when provided with the means of propulsion it shall have no inherent tendency to derange its own level. However, though as thus constructed it might, when properly balanced, be driven through the air with any velocity without losing its horizontality, so long as everything about it remained in the same position relatively to the rest of the burden as when it started, yet if the place of the centre of gravity of the load were changed, the set of the whole system would be at once altered more or less. No person could move from his seat in the boat without impairing the balance of the whole vessel. This would be more especially the case in the two-bodied craft, and in those in which all the vessels are connected by parallel cords. In the three-bodied systems, in which the principal part of the burden is collected in a vessel suspended by cords converging from all parts of the gas-vessel, any changes of position of bodies in the power-vessel will have but little effect in altering the level of the system, as this cannot be done without raising the centre of gravity of the greater mass, which will be suspended under the centre of buoyancy of the gas-vessel.

However, whatever the arrangement of the parts of the system, the gas-vessel cannot remain horizontal, unless every change in the distribution of the weight, by shifting a part of it towards either end be immediately compensated by an equivalent displacement of another part of the load towards the other end. I have already shown that former inventors have proposed a means which might be made to answer this purpose occasionally.

But, to be of the least use, the apparatus for maintaining the level must not be dependent upon the readiness and dexterity of an attendant, it must be self-acting. In a former chapter[1] I have described an apparatus which, to a certain extent, would effect this adjustment in the case of vessels suspended by parallel cords. I shall now sketch a contrivance by which I conceive an air-craft may be kept level, whatever be the manner in which the vessels are suspended, and whatever be the cause of the deviation from horizontality, provided it be not so great as to exceed the compensating powers of the apparatus.

The principle on which this level instrument is to depend is that of the plumbline—that a weight suspended freely from a point will always hang vertically below that point. This gives the key to the position of the system. If any means can be found, of compelling the axis of one of the vessels which is set parallel to the axis of the gas-vessel to lie always at right angles to a plumbline hung in it, and to return to that position if forcibly removed from it, the problem will be solved—the whole system must preserve its level.

Fig. 111.



Let now A, fig. 111, be a point in the vertical plane passing through the axis of balance of the boat and the axis of buoyancy of the gas-vessel, and let A B be a rigid pendulum hung at A, so as to turn freely in the plane of the paper, which must be supposed to be the vertical plane passing through the axis of the vessel, and let its end B be furnished with a heavy weight or bob. Let it have a tooth projecting from the side of the bob at C. Let D be a toothed wheel fixed on a spindle at its centre, and turning in a vertical plane. Let D be urged to revolve by a coiled spring. Let the tooth C on the pendulum-bob catch in a notch on the edge of the wheel D whenever the bob and wheel are in contact, and let it leave the notch and so release the wheel whenever B is removed from the toothed circumference. Let now the position

[1] See p. 331, above.

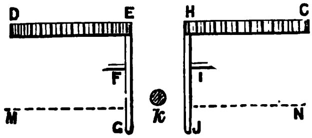
of the wheel and pendulum be so adjusted that, when the latter hangs vertically, a notch on the former shall be caught by the tooth C. It is clear then that if the frame on which A is fixed, and in which the spindle of D turns, is inclined in one direction, B will press against the edge of D; but if in the other direction, D will be released from the tooth C, and will revolve. Let now a cord be wound round a pulley keyed on the spindle of D, and let this cord be connected with a weight sliding on a rod fixed at right angles to that position of A B in which B is in contact with D, and in a plane parallel to that of the paper; and let the connection be such that, when the wheel revolves, the weight shall be drawn along the rod in the direction from B to D.[1] As soon then as B moves away from D, the weight will move on in the direction from B towards D, till B returns to its place and stops the motion of the wheel. Now A B being a pendulum hung from A, which is a fixed point on one of the vessels of the air-craft, to which the frame that supports D is also fixed, if the vessel is moved out of the horizontal position, the parts on the side of A B towards D, and the wheel D itself, will move away from the pendulum, describing a circle round the axis of balance, while A B of course remains vertical. The wheel D will therefore now revolve, and the moveable weight, being drawn by the cord away from the vertical plane through the axis of balance towards D, will continue to move in that direction, till it has so far altered the position of the centre of gravity, and has so far increased the moment of the parts towards D about the axis of balance, as to bring D back to contact with B, when the tooth on B will arrest the motion. But when D has returned to B, the position is again horizontal. So that this arrangement will compensate all disturbances of the level in which the parts of the vessel towards D move away from the line A B. Another pendulum with wheel and weight, and driven by a spring similarly disposed towards the opposite side, would be necessary to compensate the derangements of balance in the opposite sense.

Now instead of having two pendulums, a single one may be made to answer the purpose of both adjustments. Let there be

[1] As in fig 87, see p. 331 above.

two such systems as that which I have here roughly described, the two notched wheels being near together, and on opposite sides of the vertical plane through the axis of balance. But instead of their notches being caught by a tooth on the pendulum, let each be furnished with a lever detent, which shall be kept by a spring pressed against the circumference of the wheels; and let the levers of these detents lie close together in a horizontal plane, embracing between them the rod of the pendulum as in fig. 112. There C D

Fig. 112.

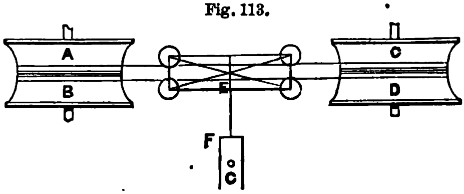


are the edges of the toothed wheels seen from above; E F G, H I J the detents with their lever arms turning about F and I respectively, K the pendulum rod in section. If now the vessel is inclined so that the whole apparatus, except the pendulum, moves towards N, the detent lever F G will come in contact with the pendulum K, and its click E will be released from the wheel D. If the system move towards M, the detent H will be similarly removed from its hold on the wheel C. If each of these wheels is made to shift a travelling weight in the direction necessary to compensate the disturbance, the level will always be preserved, or at least corrected as soon as it is impaired.

Further, a single shifting weight may be made to effect the compensations in both directions. Instead of a single pulley on the spindle of each of the notched wheels C D, fig. 112, let there be on each side of the system two barrels on an axis driven by the notched wheel; let one of them be keyed on this axis, the other free to traverse on it. Let these be side by side, so that the cord or driving band that moves the weight may be shifted from one to the other. Between the two pairs of barrels let the cord pass through a tube or double striking fork, with pulleys at each end, by which means the cord may be shifted from one barrel to the other. The object of this arrangement is, that while the cord is carried round by the barrel of one of the

wheels, it may run freely round upon the other axis without opposition. The pendulum itself must be made to shift the cord on and off the proper barrels, according as it presses on one side or on the other. This part of the apparatus is represented in figs. 113, 114. In these two figures A B C D are the four barrels; A C fixed on the spindles, B D free to move on them; E the

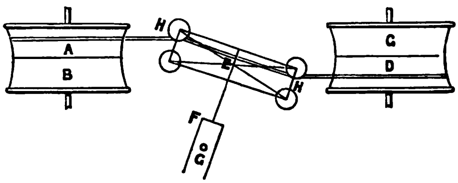
Fig. 113.



shifting tube or fork with its guide pulleys turning on a vertical axis at its centre; F the double lever arm of the shifting fork, embracing between its branches G, the rod of the pendulum in section; H H the driving cord.

In fig. 113 the system is supposed to be at rest, the vessel being horizontal. In fig. 114 the level is supposed to have been changed, and the pendulum consequently to have approached towards one side of the apparatus, so as to have thrown the driving cord on the driving pulley A, and on the free pulley D. At the same moment the pendulum will have released the wheel

Fig. 114.



that drives A, which commencing to revolve will carry the cord round, and will shift the weight which is attached to it to its new position, on the side of the system towards D.

The driving barrels which are stopped and released by the pendulum may be made, instead of shifting a weight along the length of the boat, to work a set of vertical propellers, which by acting

on the air should raise or depress the end of the vessel that had fallen below, or had been tilted above, the line of level. Such an apparatus would be closely analogous to the fins of fishes, both in purpose and in principle, for there can be no doubt that the chief use of these members is to enable the animals to preserve their balance in the water. The same end would be partially served by causing the barrels to act upon a tail moving in a vertical direction; this, so long as the vessel was in rapid motion, would keep it horizontal if properly adjusted, but would of course have no effect when the system was at rest. The shifting ballast is probably the best and simplest device for this important purpose.

I think it unnecessary to describe this level instrument in further detail, for the principle of its action must be quite obvious, and there are fifty ways of modifying the arrangement of its parts. In the form which I have described, I have supposed the driving wheels to be driven by strong spiral springs wound up from time to time, so as to keep them always ready for action. Each of the two compensating trains is supposed to be driven by its own spring; by a little further complication of the mechanism a single spring might be made to act upon both trains. Of course a weight or weights, to be wound up in the same manner, would keep the ballast adjustment in order as effectually as could spring power. The efficacy of the principle may be tested by a model of the apparatus, poised like a balance beam on a knife edge at the middle of its length. If the beam be set in the horizontal position with the pendulum hanging vertically, and if two small equal weights be hung on it, one at the extremity of each of the arms, the level will of course remain undisturbed. If now the string by which one of the weights is hung be cut, the balance will of course be disturbed, and the lightened arm of the beam will rise, but if the instrument work well, the beam after a few oscillations should return to rest in the horizontal position.

The sensitiveness of the apparatus will depend upon the weight of the pendulum-bob, and upon the length of its rod from the point of suspension to the point at which it touches the detents. For the greater the distance of any point in the rod from the point of suspension, the greater its motion for any given angle of inclination of the pendulum. And the greater the

weight of the pendulum-bob the greater its power to overcome the friction of the parts which it has to move. The power of the compensating mechanism to adjust any given disturbance will depend upon the weight of the shifting ballast, or on the distance through which it traverses, and upon the power of the driving springs or weights to move it.

The simplest form of the apparatus would be to make the pendulum itself very heavy, and to make it do the work of sliding the ballast to and fro. The upper end of the pendulum rod, prolonged above the point of suspension, would be furnished with a toothed arc which, working backwards and forwards on a pinion, would drive the compensating train in either direction with equal readiness. It would only be necessary to provide, by a very simple adjustment, that the pendulum should only act on the train in those movements of the system in which it is leaving the horizontal, and not during the return oscillation; for if this were not provided it would, of course, in returning undo the change effected during the previous motion. With this form of the apparatus, the bob of the pendulum would of course be made a receptacle for a part of the heavy cargo, to avoid the necessity of carrying extra load.

The point of suspension of the pendulum may be anywhere in the vessel, provided only that it is placed sufficiently high above the point of its action on the machinery. It is better that it should lie in the vertical line passing through the axis of balance, both for the purpose of placing its mere weight in the position where it will tend most to promote the stability of the poising, and to give equal room on either side of it for the free traversing of the shifting ballast-weight. But this latter point is not necessary, it is only a question of symmetry; for the zero point of the level weight need not be in the same part of the length of the vessel as is the pendulum, nor indeed need it be in the vertical plane passing through the axis of balance; for if its moment about that axis is changed in the right sense and to the required amount, the proper compensation will be effected. If the pendulum be suspended at this axis, its plumb-bob will, unless the air-craft be actually in locomotion, always remain at rest; the other parts of the boat moving with respect to it will

start the mechanism, by pressing the appropriate lever against the unmoved pendulum. If it hang from any other point, it will of course share the oscillation of the system. It will produce the same effect from whatever point it is hung, as the amount of its action on the mechanism at any instant depends entirely upon the angle at which the axis of the vessel is inclined to its original position. If the weight of the pendulum is considerable with respect to the burden of the vessel, it must be hung directly below the axis of balance, as it will, in that case, always tend by its own weight to bring the system back to its proper level. If hung from a point above the axis of balance, it will tend to derange the level; if from a point within that axis it will be indifferent. If suspended from a point on either side of it, the pendulum must be counterpoised by a fixed weight on the other side of the same axis.

There will be one condition in which it will be necessary to provide against an actual deviation of the pendulum from the vertical, lest such alteration in its position should produce the effects which are only intended to follow the departure of the vessel in which it hangs from the horizontal, while the pendulum itself remains perfectly downright. This error may occur when the air-craft is commencing its motion, coming to rest, or changing its velocity. It will arise from the inertia of the pendulum-bob, which will tend to continue at rest, or to move with the same velocity with which it was proceeding before the change. If the mass of the pendulum is large with respect to that of the whole burden, the effect will be considerable; if the pendulum-bob is small, it will be unimportant. It will, however, be easily avoided by putting the compensating apparatus out of gear, or by fixing the pendulum-bob to the vessel during these changes, which will be but transitory.

The use of this level instrument will not supersede the necessity of another larger shifting ballast to be moved by hand on occasion of any graver pitching or tilting of the vessel. The self-acting mechanism would meet all the minor variations of level arising from movements of the passengers. In small air-craft of course the passengers will have to sit still as in a carriage or small boat. In large vessels their movements will be but

little felt, though of course they must never rush all at once to one end of the boat, lest a catastrophe should ensue. Means will of course be adopted to make such a movement impossible. It will be easy, if requisite, to apply the same pendulum principle to the correction of the lateral balance of the vessel. I apprehend that thus the air-craft may be preserved from all tendency to take a false set, as respects both its cut and trim.

CHAPTER X.

CONDITION 8.—THE VESSEL MUST BE ABLE TO KEEP A LEVEL POSITION WHEN FLOATING AT ANCHOR, AND TO LAND ITS PASSENGERS WITH SAFETY.

THE air-craft when at anchor in a calm, with its load exactly counterpoised by the lightness of its gas, will be affected by changes in the position of its burden, as respects its balance of level, in exactly the same manner as if it were floating freely at rest or in motion. The fact of its being unable to move far from its place will not make it the less necessary, so long as its passengers are on board, to keep it in true level trim. The apparatus described in the last chapter will effect this. If, however, the air still being calm, the lifting power of the gas exceeds its burden, a new force is introduced, for now the anchor rope will have to resist the rising tendency of the craft, and therefore will be kept in a state of tension. If it is at anchor in a wind other considerations will be added to the problem; the affections of the system being closely similar to those which belong to it when urged by a propelling force against the air. Under a wind, too, the conditions of the mooring will be different, according to the circumstances of the buoyancy of the system. Firstly, then, the vessel having only a part of its cargo on board, the float may have an excess of lifting power. Secondly, the craft, being fully freighted, may be in perfect equilibrium with the air as respects floatage. I shall consider these two cases separately, introducing under each head the variations in arrangement that will be required in event of wind.

Now the matter chiefly to be considered is, How are the lines connecting the air-craft with the earth to be attached to the former?

If the gas has an excess of lifting power, and there is no wind, the craft will be carried up by its floatage until it is directly above the anchor or point at which it is tied to the earth. Having arrived at that height it will arrange itself, supposing that the mooring line is attached to it at a single point, so that its centre of buoyancy shall lie as high as possible, that is to say, directly above the point of attachment of the cord which restrains. It will, in fact, be balanced about this point as respects its upward effort exactly as, when the specific gravity of the whole system is the same as that of the air, its weight is poised about its centre of buoyancy. The mode, then, in which it should be tied to the earth below is exactly similar to that in which a weight, such as a long log of wood, should be hung from a point above it, so as to keep it lying horizontally. The point or points of attachment must be taken with respect to the centre of buoyancy of the gas-vessel, just as those of suspension would be selected on the log. Again, these points may be taken either on the gas-vessel or on one of the vessels slung to it, but the mode will be the same in either case. If, then, there be only a single cord used for anchoring the craft, it must be fixed to one or other of the vessels at a point exactly below the centre of buoyancy of the gas. The only part at which this can be taken is obviously at the bottom of the lowest boat, for its direction must pass through the centre of gravity of the burden, and would therefore, if taken on an upper vessel, pass through the body of those below it. In illustrating these modes of anchorage, I shall confine myself to the case of the two-bodied air-craft with parallel suspen-

Fig. 115.

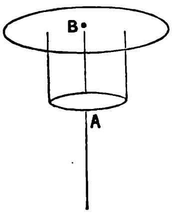
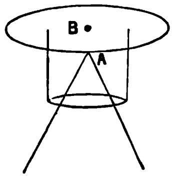


Fig. 116.



sion: the application of the same principles to the other forms is clear and simple. Fig. 115 will represent such a system

anchored in this manner. The craft may, of course, be anchored by two cords diverging from a single point of the gas-vessel, as in fig. 116. In either of these cases the system is balanced about the point A, to which the cords are attached, and over which the centre of buoyancy, B, lies in a vertical right line. But if there are to be two cords and anchors, there may as well be two points of attachment on the air-craft. For in this case the vessel will no longer be balanced about a point, but will be stable in its position, like a log hung by two points in its length. The further apart, and the nearer to the ends of the vessel these points are taken, the more stable will be the level. It is of no importance whether the mooring lines in this case are attached to the gas-vessel or to the boat; nor, so long as the air is still, does it matter at what angle they are inclined to each other. Fig. 117 represents the air-craft moored in this fashion. However, if the cords were not parallel, this might be a dangerous mode of attachment, for if the wind should suddenly commence to blow from head or stern the craft would be upset, by pitching end foremost.

Fig. 117

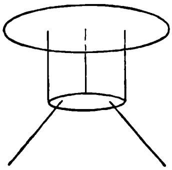
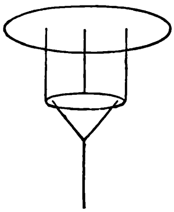


Fig. 118.



But there may be two points of attachment on the vessel and only one anchor with a single cord running up from it, and separating into two branches above, as in fig. 118. This, as will be seen presently, is by far the best and safest mode of suspension. For the system is not balanced about a point and is yet free to turn in any direction horizontally if the wind should rise, leaving only a single adjustment to be made, of which I shall have to speak immediately.

We may now consider the second division of this case—that of buoyancy in excess with wind. In treating this I shall, for

the sake of simplicity, suppose that the unbalanced residue of the lifting power of the gas bears to the force of the wind such a relation, that it will sustain the craft at a sufficient height to keep it free from all danger of being driven to the ground by the joint action of the wind and of the tension of the mooring cable.[1] The requirements of the craft in all instances in which, though the lifting power be more than equivalent to the weight of the burden, it is not sufficient to resist the downward twisting of the wind, will be met by the provisions of the second case.

An air-craft tied to the ground by a single cord attached to a single point of its system, if exposed to the pressure of a constant wind, and having sufficient rising power to keep it in spite of the current at a certain height above the ground, will be in exactly the same conditions as respects its balance of level, as if it was being propelled forward against the air by a force applied at the point at which the cable holds it. The reasoning, then, that determines the conditions of the propulsion of gas-vessels, applies equally to the anchoring of them in a wind. It is necessary that the point or points of attachment of the cable to the craft must be so chosen, and the cables so adjusted, that the wind shall not be able to twist the system in a vertical plane. There are three forces acting on the system: the horizontal force of the wind, the vertical upward force of the buoyancy, the tension of the mooring ropes. When the system is at rest under the action of these forces, the latter of them balances the other two; the resultant, therefore, of the tension of the ropes must coincide in direction with the resultant of the wind-pressure and the floatage. Let, then, fig. 119 represent a gas-vessel acted on by the wind (P), horizontally through its long axis, and by its buoyancy (B), acting vertically through its centre of buoyancy. Through the centre of buoyancy of the vessel draw A B vertical, cutting the long axis in A; take A P horizontal through A; and A B proportional respectively to (P) and (B); and let A D be the diagonal of the parallelogram, of which A P, A B are the sides. Produce D A to (the earth at) C; A C will be the direction of the resultant of these forces, and will therefore be that of the tension of the mooring lines.

[1] See p. 170 above.

If there is but one cord and one point of attachment, the cord must lie wholly in the line A C, and the only point on the gas-vessel to which it can be attached is D, where the line A C meets

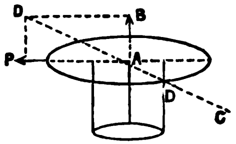


Fig. 119.

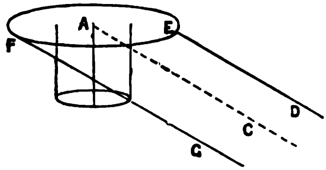
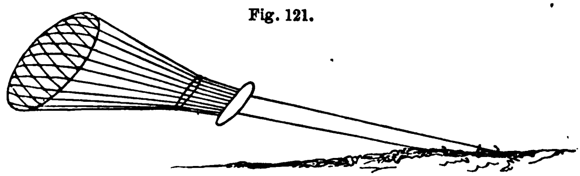


Fig. 120.

its bottom. Again, if there be two cords, or if the one cord be forked so as to have two attachments, both may lie in the plane which passes through the line A C, and the short horizontal diameter of the vessel at A. It is clear, also, that any cords stretched parallel to A C, and in the plane passing through the long axis of the vessel, will hold the system at rest, as in fig. 120, provided that they lie as E D and G F on opposite sides of the required resultant line, A C. If the parallel cords are equidistant from A C their tensions will be equal, if not they will be unequal, the nearest one bearing the greatest strain. This arrangement of parallel mooring lines has the great advantage that, whatever may be the force of the wind, so long as its direction remains the same, straight from the head, the vessels will lie perfectly horizontal; since, however the wind may thrust the air-craft down, or allow it to rise, it will always move parallel to itself. For a craft anchored with the intention of riding out a gale of probable long continuance, this would be a very excellent adjustment. The head of the vessel would, of course, be moored right up the wind. The arrangement of parallel cables, however, can only be made after having come to anchor in another way; for neither the head cable nor the stern one could be allowed to take its hold first, lest the other end should immediately rise; and the two never could be made with certainty to grip the earth at the same instant. If, however, the wind should shift to any other quarter except the direct astern, the craft would be in danger of being blown to the earth or upset, especially, if, as in fig. 121, a perspective sketch, the anchor cables are supposed attached to the boat. This liability arises from the far greater resistance

offered to the wind by the broadside of the vessel, and from the new position of the centre of buoyancy with respect to the lines

Fig. 121.



of force of the mooring cables. If in such case the wind did change, it would, of course, be necessary to send a man down, to make fast another cable from the stern in the direction down the wind, and to take up the former stern anchor.

It is necessary, therefore, to seek a method of mooring which will keep the vessel ready, as far as possible, to meet all changes in the direction as well as in the force of the wind. In propelling the vessel through the air, the chief object is to sling the power so as to keep the level constant, although the force of the propulsion may vary, without much regard to changes in the direction of motion. For the latter changes will be less frequent, and will never be in the sideway direction, so as to expose the system to the broadside pressure with which the wind may attack the anchored craft. In navigation, therefore, the chief end sought, as respects the application of the force, is best satisfied by the parallel sling lines. But the case will be different in anchoring the craft, because changes of direction of the wind are here fully as dangerous to the balance as changes of its force. However, the system of parallel anchorage may be adapted to changes of the wind thus: Let the two parallel cables, E D, F G, fig. 120, instead of being

Fig. 122.

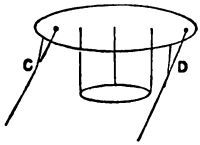
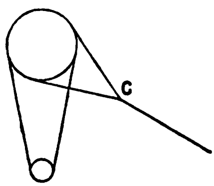


Fig. 123.



attached to the bottom of the gas-vessel, each terminate in a pulley, as at C D, fig. 122, through which is reeved a long line,

running up to the gas-vessel, and having its extremities fixed to the extremities of horizontal diameters of that vessel near its ends. If, now, the wind changed to a direction at right angles to its former course, the system would assume the position shown in an end view, in fig. 123. The weight of the boat, aided by the pressure of the wind on its broadside, would tend to keep its short horizontal diameter as well as that of the gas-vessel horizontal, and thus in assuming its position below the gas-vessel, it would draw the branch cable through the pulley, and so keep the system in proper form. On this mode of mooring it may be remarked that if the wind is very high, and the cables are not fixed to the vessel pretty near its ends, the head cable will come in contact with the head of the boat at a certain inclination of the system, which would be inconvenient. Again, if the cords be applied to the boat in this manner instead of to the gas-vessel, the boat would be pulled out of the horizontal set laterally by the dragging of the gas-vessel, like a ship on her beam-ends, as in fig. 124, where the dotted line, A B, marks the plane of the horizontal diameters of the boat. This inconvenience, however, might be remedied by substituting for the pulley at C a fixed junction of the cords; and by providing within the boat the means of shortening up and of lengthening out at pleasure one of the branches of each cord; by this means the boat might be kept

Fig. 124.

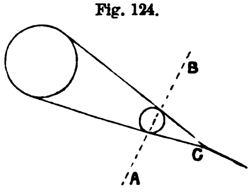
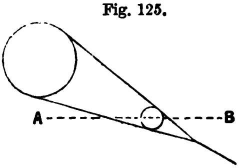


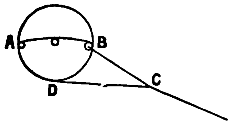
Fig. 125.



level, but it must be remembered that in this case nearly the whole strain, both that due to the sling-lines and to mooring ropes, would be thrown upon those on the windward side. Such an arrangement is shown in fig. 125. The branches of each anchor-cable running to the boat from C proceed to the extremities of a horizontal diameter of the vessel, where one of them is fixed, and the other, passing through the side of the boat, is fixed to a windlass cylinder for altering its length; or the two may be continuous,

and pass through the sides of the boat and round a cylinder within it,—the latter would probably be the safer arrangement, as shown in fig. 126. An air-craft provided with such a system of anchorage would be able to suit itself to all winds, whatever their force or direction—when once anchored. But there would be these inconveniences attending it,—

Fig. 126.

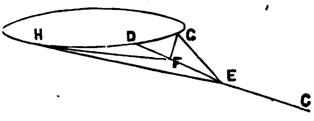


firstly, when the wind is on the beam, the gas-vessel would be exposed to great pressure on its whole broadside, which would force the craft very low towards the earth, and would require the cables to be immensely strong; secondly, the cord A B C D (fig. 126) could not be shifted without friction on the bottom of the boat, as from D to A; and thirdly, before the mooring can be accomplished, the system must be anchored in some other way from a single point on the ground.

There must, then, be some other mode of holding by mother earth, for the service at any rate of coming to anchor at first. And the question will be, whether such a system will not meet all the requirements of the craft in ordinary service. Let us now return for this enquiry to our hypothetical case of equilibrium, and to the diagram illustrating it, fig. 119. Let the vessel be held at rest by the cord C D, stretched from the earth in the direction of the resultant of the lifting force and the wind-pressure. It is clear that a pair of cords may be stretched from any point whatever of D C to any two points on the lower surface gas-vessel, which can be reached by straight lines drawn from the first point. Again, if these points be taken on opposite sides of D and in the same plane with D C, that is to say, in the mid-line of the vessel's bottom, it is evident that the two cords may be drawn tight without deranging its level, or altering the position in which it faces the wind. When this has been done, the middle cord may be cut away without affecting its position, the strain being borne by the two branches exactly as before by the single cord. Thus, in fig. 127, C D, being the position of a cord which will retain the gas-vessel, H D G, in a horizontal position, under a given lifting power and a given force of the wind; and E F any points in its course; and H G, any points on the mid line

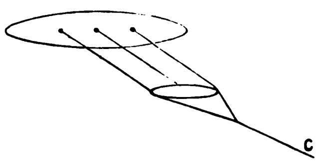
of the gas-vessel's bottom; the system will be retained in the same position by the cord C E, with the branches E G, E H; or by the cord C F, with the branches F G, F H. But it is quite obvious that if the force of the wind is increased or diminished, and consequently the angle which the anchor-cable makes with the ground altered, the vessel will no longer remain horizontal, if the branch cords E G, E H remain of the same length. However, the air-craft will be perfectly free to obey every change in the direction of the wind, just as a boat anchored in a tideway shifts round as the current changes. It is further evident that nothing else is necessary but the means of readily altering at will the relative length of the two branch cords, to enable the master of the air-craft to maintain his vessel in perfect level, notwithstanding the change in the force of the wind. With this adjustment, then, the system may be abandoned at its moorings freely and fearlessly to the gale. It will always present its head to the current in the line of its resistance, and so will tax the strength of the cable in the least possible degree.

Fig. 127.



Now the conditions of the equilibrium of level will not be at all altered if we attach he mooring lines to the boat. The system, when at anchor in a uniform wind, will with this arrangement dispose itself as in fig. 128. The method of anchoring from the boat, or from the lower boat if there be more than one, is obviously the best, not only for the reason that the mooring lines cannot interfere with the other cordage or vessels of the system, but because the manœuvres of the anchor and cable will be more easily managed, and the means of making the adjustments of the branch ropes will be ready at hand. The arrangement will be extremely simple; the anchor will be attached to the extremity of a single cable, of sufficient length to enable the craft to float at a considerable height in the air. At its upper extremity this cable should

Fig. 128.



be shackled to two branch hawsers, one of which runs to a point towards the stern of the boat at the bottom, the other towards the head. One of these may be attached immovably to the bottom of the boat; the other in that case, which might be called a bridle hawser, must pass through the bottom and be wound upon a capstan cylinder. Or the two branches, both passing through hawser-holes in the bottom of the boat, and over pulleys, may be continuous with each other, being wound round a cylinder in the middle of the vessel; so that by turning the cylinder one way or the other the relative length of the branches may be altered. If the wind should fall off, and the craft therefore rise in the air, the head of the vessel will dip downwards; in that case the fore branch will have to be lengthened and the after one to be hauled up, and conversely. Now this level apparatus may be made self-acting, so as not to require constant attention. Let any sufficient source of mechanical power, either the propelling engine of the vessel, or a powerful spring, or other reservoir of force specially devoted to the service of the anchorage gear, be connected with the winding cylinder by any form of mechanism capable of transmitting motion to it, in either of the two directions in which it can revolve. Let there be a pendulum —the palladium of the future aeronaut—in combination with this, and arranged in any of the hundred possible modes suited for this purpose, so that the power shall not act so long as the pendulum hangs at a right angle with the long axis of the vessel, but so that as soon as the vessel dips, either by the head or by the stern, the winding cylinder shall be caused to revolve, so as to correct the trim. A pair of detents must be arranged so as to catch the cylinder, and to prevent it from being turned by any unequal strain upon the two cords when the position is horizontal,—the pendulum must, of course, release the detents at the same instant that it starts the winding mechanism.

But with this arrangement alone, the vessel could never be anchored under a given wind except at one particular height, for the length of the anchor-cable by which it is attached to the earth would be invariable. Again, if it should be desired to maintain a constant height, this could not be accomplished if the force of the wind should change, without paying out or hauling

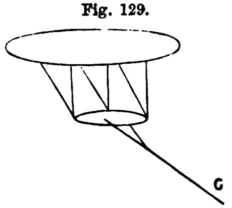
in some of the cable. Some means must, then, be contrived of effecting this adjustment. This may be in two ways, either by making the length of the branch hawser or that of the main cable itself variable. The first mode could only be managed by winding the two hawsers on separate cylinders in the boat. These two windlasses should be connected together by two trains of toothed wheels, one train at each extremity of the cylinders. One train should contain an odd, and the other an even number of intermediate wheels between the two barrels, and they should be so arranged that when one is put into gear the other must be thrown out. Thus, if the first train were in gear and driven round, the two cylinders would turn in the same direction, and both of the two branches would be either lengthened or shortened at the same time, according to the direction in which the cylinders were turned. But if the second train were worked, the two cylinders would be turned in opposite directions, and would thus lengthen one and shorten the other of the branches, according to the direction in which they were driven. By means of the former train the height of the craft above the ground would be regulated; the latter would govern its level or inclination in the air. The former, of course, would only be worked by hand, or by artificial power, at the will of the master of the vessel, and would only be thrown into gear when required. The latter would be kept in gear, and would be connected with the self-acting level-governor.

The same end of adjusting the height above the ground may also be attained by lengthening the cable itself, the sum of the lengths of the two hawsers remaining constant. This may be done in two ways, either by attaching to the anchor or mooring block a pulley through which the cable is reeved, one end of the cable being, as before, fastened to the branch hawsers, and the other brought up to the boat, within which it is wound about a barrel. Or, one end being fixed to the anchor and the other end coiled or wound up in the boat, to which also it is made fast; the cable thus arranged may pass through a tube fixed at the shackle which unites the hawsers, in which it can traverse freely when it is desired to lengthen or shorten it. But that the tension of the cable may be properly transmitted to the boat, it must

be fastened to the branch hawsers at the point at which it meets them. For this purpose the tube through which the cable runs must be armed at that point with an apparatus by which it can clip the cable tightly, and so prevent it from slipping through. This clip must be furnished with a trigger, by which with the aid of a cord running to the boat it may be made to release the cable; it must be closed by a spring which, when the trigger-cord is slackened, shall cause it to grip the cable. By this means the cable may be run out or hauled up, and the height in the air at which the craft shall float may be varied at pleasure.

One other mode of arranging the mooring line may be mentioned. The action of the anchor by its cable on the gas-vessel in a wind is precisely similar, as has been said, to that of the boat when propelled upon the same part of the system. Any mode by which the burden may be slung is therefore equally applicable to the anchor-tackle. The hawsers may, therefore, be attached to the gas-vessel on opposite sides of a vertical line through the centre of buoyancy, as in the first case of the suspended flyer.[1] If, therefore, they are attached to the pair of sling lines that lie in the plane of the centre of gravity of the boat, and of the centre of buoyancy of the gas, this condition will be represented. The only point, however, in their length to which the anchor can be connected, without deranging the parallelism of the system of suspending cords, is at the point where they are fixed to the boat. Fig. 129 represents this arrangement with a single cable and branch hawsers, which must be long enough to clear the sides of the boat.

Fig. 129.



We may now fearlessly leave our air-craft with excess of buoyancy riding at anchor in a wind; and may consider the case—the more important one, and that which will most frequently occur—of the air-craft with its weight counterpoised by the gas without any excess of floatage. If there be no

[1] See p. 307 above, figs. 49–50.

wind, the conditions of its balance of level will, as I have before said,[1] be the same as if it were not tied to the earth. It will, however, always float just at the greatest height to which the length of the cable will allow it to rise, that is, supposing the anchor and cable form part of the counterpoised burden of the vessel. For as soon as the anchor and any of the rope attached to it is laid upon the ground, the vessel being relieved of so much weight will rise. The hawsers will, of course, be attached in exactly the same manner as in the case of the air-craft with lifting power in a calm.[2]

However, if the wind is blowing the conditions are altogether changed. It is quite evident that if the air-craft be moored to the earth by a cord of any length, and if the vessel, having no lifting power, be exposed to a wind, however slight the force of the latter may be, it will be sufficient to drive the system to the ground, and will, in fact, inevitably do so. This result can only be avoided by communicating to the vessel an upward force, which shall be sufficient to keep it at the required elevation, notwithstanding the force of the wind. This might be done by giving to the vessel for the time a greater buoyancy, either by discharging ballast or cargo, or by sending into the vessel a further supply of gas. Both of these devices will, of course, be made use of sometimes, and when either of them is practised, the conditions of the craft will approach more or less closely to that of the case just discussed at length. But this will not be sufficient for general purposes. Some other mode of obtaining lifting power must therefore be resorted to. A constant downward force exerted by some propelling mechanism, such as a screw propeller or fan-blast driven by power within the vessel, would, of course, answer the required end. But, as has been already pointed out by M. Monge,[3] the wind itself may be made to do the lifting work, and so to oppose its own depressing effect. The kite is the apparatus by means of which this is to be effected. M. Monge proposed to make the gas-vessel itself serve the purpose of a kite. I endeavoured to show in the place just referred

[1] See p. 365 above. [2] See figs. 115–118.
[3] See p. 171 above.

to why I believed this mode to be improper for practice. The air-craft must be furnished with a kite plane specially adapted for this end. I shall hereafter have to show [1] that this apparatus will have to answer another most important purpose in the economy of the air-craft. To propose, therefore, to add to the burden of the air-craft such an appendage as that which I have now to describe will by no means be to load it needlessly with superfluous fittings.

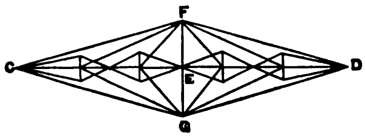
There are many forms and modes in which this contrivance may be adapted to the air-craft. I shall describe but one, that which I believe to be the best, and shall speak of its rigging as applied to the air-craft with parallel suspension, taking for simplicity the case of the two-bodied craft with gas-vessel and boat below it. The imagination of the reader will no doubt supply arrangements of the kite-plane in the other species of aerial vehicles.

Now the next effect which the kite when in action will produce upon the system, will be a force of traction upon the boat, resolvable in two directions. One part of this is a horizontal pressure, which acts upon the system as additional to the pressure of the wind upon the gas-vessel, the other part is a direct upward lifting force. This latter force will act upon the system as would an additional gas-vessel; if not applied in such a manner that its resultant passes through the centre of gravity, it will tend to twist the system about that point, and will require an adjustment of the centre of gravity to prevent it from deranging the level. It will therefore be desirable to attach the kite to the craft by cords, lying symmetrically on opposite sides of the centre of gravity in its normal position, so that the resultant of their tensions may pass through that point. Now our air-craft is constructed so as to offer special facilities for this mode of slinging the kite. The plane surface of the kite, which is to receive the pressure of the wind, must, of course, admit of being adjusted to any angle with the horizontal, to suit various conditions of the wind and of the craft when at anchor, as well as for other purposes which I shall have to mention hereafter. That it

[1] See Chap. XIII. below.

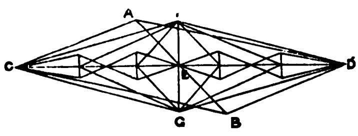
may require the least amount of force to alter its inclination at any time, it must be poised about an axis passing through its centre of gravity, and parallel to the plane of its working surface. Now the cords by which the boat is slung to the gas-vessel offer the most convenient means of suspending the plane; a pair of these will naturally run up from the boat on each side of its middle, near which the centre of gravity will of course lie in the normal position of the craft. The kite then will be slung on a horizontal axis attached to the two opposite sling-lines of the boat that lie nearest to the middle of its length. The kite itself must be an extensive surface, constructed of the lightest materials that are consistent with greatest strength. It must not only not be liable to bend itself, but its axis must be strong enough to communicate the whole pressure which the surface sustains to the cords which receive its ends, and transmit the force to the boat. The framework, therefore, of the kite will be made of bamboo, with a strong canvas or linen sail stretched over the whole of it. It will be tied and stayed in every direction, so as to give it the greatest possible strength and stiffness. Its main cross-bar will terminate in metal axles, which will work in strong collars in the two sling-ropes. The kite itself will be such a

Fig. 130.



structure as that represented in figs. 130, 131, whereof the first represents the skeleton of the framework that supports it, in side

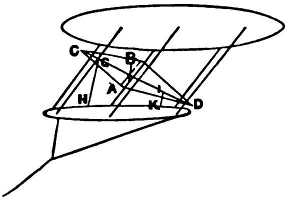
Fig. 131.



elevation; and the second a perspective view of it with the sail web stretched in its place. A B, fig. 131, are the axles of the

frame, at the extremities of a strong compound bar of bamboo, constructed so as to have great strength and rigidity; C D is the backbone, a bamboo rod tapering towards each end from the centre at E; E F, E G a sprit of bamboo fastened to the centre E, and projecting on each side of the plane of A B and C D at right angles to them, to a sufficient height to enable it, by braces stretched from its extremities to various parts of A B, C D, to give support to the backbone and axletree. Other sprits and stays will be added as may be required for the strength of the system; A C B D will be similarly joined by braces from their ends and intermediate points, so as to give strength to the kite in the direction of its own plane. The web will be stretched tightly between A B and C D and the cords joining their extremities. Fig. 132 represents the air-craft anchored with its kite inclined to the wind, and supporting the system. A B are the axles; C D the backbone of the kite. The angle at which the kite meets the wind will be determined by the cords G H, I K, which can be lengthened and shortened reciprocally. The length of the sling-lines from float to boat must be such that the kite can have free room to turn through 180 degrees, without either of its ends coming into contact with either of the vessels in any position of the craft, even when the kite lies completely in a vertical plane, and the gas-vessel and boat are brought as near together as they can be, by the greatest resistance which the former meets during the swiftest flight of the craft. The cords G H, I K must be strong enough to bear a part of the traction of the kite, so as to relieve the axles A B, and the backbone C D, of the strain to which they would be subjected without this assistance. These two cords must be limbs of one continuous rope, and at the points where they reach the boat must pass round pulleys, of which the position may be shifted so as to keep the rope tight in every position of the kite. Finally, between these pulleys the rope must be wound upon a barrel, just as are the hawsers described above, so that by turning the cylinder the angle at which the kite is set may be altered.

Fig. 132.



The kite will, of course, during ordinary horizontal flight, when the buoyancy of the gas is exactly counterbalanced by the weight of the burden, lie exactly in a horizontal plane, so as to offer the least possible resistance to the air in its progress. The angle at which it is set for anchorage must depend on its size, or the height above the earth at which it is desired to ride (that is to say on the angle which the anchor-cable is to make with the horizontal), and on the force of the wind conjointly. Its size must be determined by the size of the gas-vessel, and by the coefficient depending on the form of the latter, and expressing the ratio of the resistance with which it meets the air, to that presented by a plane surface of the area of its greatest vertical section.

It is obvious that the craft, when thus furnished with a kite that will sustain it in the air, is in exactly the same condition as respects fitness for anchoring or mooring, as is a vessel suspended from a buoyant float. The same modes of attachment of the cable and hawsers as have been described above for the case of the former arrangement are equally applicable in the present instance. Nothing, therefore, need be added here to the discussion of the methods of anchorage.

The air-craft, being now provided with means of riding at its moorings in all weathers without fear of being upset, may venture to come to anchor. If the air is calm, this will be a very simple matter. Either the boat itself will be brought down to earth, or a man will be lowered in slings with a rope which he can make fast to some fixed object, or with means of driving an anchor into the ground. Or a man may slide at once down the cable and fix the anchor, while the propelling power in the boat works an upward waft for the purpose of compensating for the loss of his weight, and neutralising the lifting power thus set free in the float. If the vessel has already an excess of buoyancy, of course the same device must be resorted to at first in the descent. If a wind is blowing, the head of the craft will be turned weatherwards, and by means of the propelling power will make way against the current, till arrived at a point higher up the wind than the intended anchorage. The anchor will then be lowered, and the speed of the propellers slackened, so as to allow the craft

to be carried gently down the wind till the anchor takes its hold. Meantime everything has been made ready to adjust the kite-sail to its proper angle with the air-stream; as soon as the anchor catches, the kite will be at once tilted up in front and down towards the stern. The expert navigator will know the angle at which it must be fixed; the unpractised one will easily find it on trial. The propelling power will be employed to sustain the vessel against the pressure of the wind, until the kite being properly fixed is ready to supply its place.

But we have yet another part of our requisite to fulfil. The passengers must have means of landing in safety. If the air is calm, and the vessel, having descended to the surface, has been secured to earth head and stern, they may at once step aground. If the craft is floating above the earth, they will be lowered in cradles by tackle specially provided for this purpose. They will debark from the boat through a hatchway in the centre of its bottom, which is provided specially for the purpose of receiving and discharging the burden at a point immediately below the normal position of the centre of gravity of the vessel. This provision will be necessary, for the purpose of maintaining the level of the system. Nothing, of course, will ever be thrown overboard without the orders of the captain; all scraps of waste will be carefully collected, and thrown into the waste ballast-box, close to the hatchway, for use upon occasion, or for discharge at the end of the voyage; and when anything is thrown overboard it will always be from the central aperture. This hatchway will be completely closed from below by the landing cradle while the passengers are getting in, so as to prevent the possibility of anyone falling overboard in the attempt to get into the cradle.

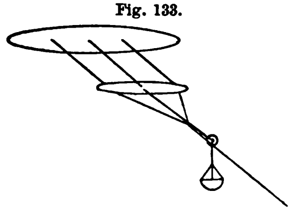
If, however, the vessel is riding in a wind, it may not be safe to lower the passengers and other fragile goods directly from the boat to the earth. For, in the first place, there will generally be an up-and-down swaying motion of the air-craft, arising from variations in the force of the wind. This might cause the weight that was being lowered from it to be struck suddenly upon the ground; and if this occurred once, it would set up a series of oscillations which would greatly increase the inconvenience; or

in the second place, even if the cradle was lowered quite steadily and gradually, as soon as it reached the earth and the burden rested upon it, the gas-vessel would be relieved from the weight, and would tend to spring upwards. And if the load were suddenly deposited upon the ground by a downward jerk of the vessel, the float would certainly mount immediately, with the whole force due to the weight of which it was relieved. Its upward momentum would carry the cradle again off the ground, which with the returning swing would be again let fall upon the earth, and so on, each time with increased violence, unless it were seized and secured by some one ready to receive it.

But the very arrangement of the whole system when at anchor is such as to provide the very best and safest means of transferring the passengers and goods to the earth. The anchor-cable itself slanting downwards offers the best line of conveyance that could possibly be desired from the boat to the earth. The mode which should be adopted is one which I have seen at the great slate quarries at Delabole on the north coast of Cornwall for lowering the workmen from the surface to the bottom of the vast precipitous pit from which the slate is extracted, for bringing up the stone from the bottom, and for loading with it the vessels which are moored at sea under the towering rock-wall that girds the coast where Arthur reigned. A rope or chain is stretched, sloping down at an angle of some forty-five degrees from the top of the cliff to the ship's deck, and is made fast at each end. On this guide-line there travels a pulley, from which hangs the kibble or iron basket with its load. To the pulley-block is fixed the end of a rope, which is wound on and off a barrel by a capstan on the cliff. And thus the load is let down from the heights above to the ship or pit's bottom, running down the catenary of the guide-line, which, as would an inclined plane, bears its share of the burden, and delivers it below steadily and exactly at the point required. Now, our anchor-cable provides us with this guide-line, which the wind will keep strained at any angle that we may desire for our path. The cradle which carries down the passengers to the landing is to be slung from a pulley which traverses on the cable. To the pulley-block is to be fastened a rope, which, being wound on a barrel in the boat, will be the

means of raising or lowering the burden along the cable. It will also be necessary to have, traversing on the cable just above the pulley, a spring-catch, constructed so that it should clutch and firmly grasp the cable, as soon as the weight of the descending burden might be thrown upon it, if the cord by which the cradle is lowered should break. Fig. 133 represents the air-craft and travelling cradle, as in use for disembarking passengers. It is obvious that by this mode the load must reach the earth with the most perfect quietness. Indeed, even if the boat above were plunging up and down unmanageably, the oscillating motion would scarcely be perceptible in the landing-cradle. The link of rope by which the latter hangs from the cable must be sufficiently long to admit of the vehicle being drawn up to the hatchway from the point at which the cable joins the hawsers, above which point its weight must be borne entirely by the lowering rope. In the case of a large air-craft, there will often be two diverging cables running down to their anchors from the point where the hawsers branch; it is obvious that the debarking process will be very much expedited by running a carrier-cradle on each of them, so that they might work alternately, the loaded one pulling up the other empty.

Fig. 133.



During the whole of the traffic up and down the cable, the weight will be thrown directly in the line of tension passing through the centre of gravity. The level will be undisturbed, except by the changes of the direction in which the cable meets the hawsers, which will ensue as the weight is thrown successively on different parts of the length of the former rope. But these changes will be regular and continuous throughout each journey of the cradle; and they will be regularly compensated by the level instruments in the boat, which will cause the hawsers to be shifted steadily to and fro, so that the vessel will never be thrown out of the horizontal.

We have now completed the consideration of the conditions relating to the balance of level of the craft. The balance of buoyancy has the next claim on our notice.

CHAPTER XI.

CONDITION 9.—THE BUOYANCY OF THE GAS MUST EXACTLY BALANCE THE WEIGHT OF THE CRAFT.

THIS requisite of the balance of buoyancy is a very simple matter in its first aspect. All that it seems to require is, that—either given the burden to be carried, just enough gas must be thrown into the envelope to neutralise the weight; or—given the lifting power of the float, just enough weight must be placed in the boat to neutralise the buoyancy. But it is not only necessary that this should be secured at starting, the balance must be permanent, notwithstanding any influences which may tend to derange it. Firstly, then, we must get the specific gravity of our system adjusted so as to be exactly the same as that of the air. Secondly, we must keep it so.

I shall commence, then, by showing how the preparation for the voyage is to be made in this respect. Next I shall consider what causes will be at work to alter the equilibrium. Lastly, I shall have to show how the effects of these may be counteracted, so as to maintain the required condition.

When a gas-vessel is built, strict account will be kept by the clerk of the works of the weight of all the material put into its construction. The cubic contents of the envelope will be known approximately. These data will inform the engineer roughly of the duty of the vessel, as respects lifting power, when full, half full, or containing any given amount of gas. The first event in the life of the new craft will be its launch. This will be done by filling it with gas. The quantity of gas thrown in will be measured, and the amount of it noted as soon as the vessel just floats. The specific gravity of the gas being known, this quantity will be of use for correcting the estimate of the weight of the

vessel. The envelope will now be completely inflated with gas, its cubic contents noted down from the gas-meter, the temperature of the air observed, and the lifting power of the full vessel ascertained. It will then be allowed to retain its charge for some days, and the weight which it lifts observed from time to time at different hours of day and night, and at intervals when the temperature of the air is the same as when it was first filled. From these observations the behaviour of the vessel as respects the most important of its qualities, namely, its retentiveness of gas, will be learned,[1] as well as its liability to be affected by changes of external temperature. The actual duty of the vessel is now known, and if it is not wanted for immediate use, the gas, provided that it is not impaired by transfusion of air into the envelope, will be returned to the reservoirs of the establishment. This, of course, will be effected by simply tying the hose of the envelope to the pipe from the gas-holder, and by then raising the bell of the latter by mechanical power.

When the gas-vessel is required for a voyage, the weight of the boats and of the whole burden to be attached must be ascertained as nearly as possible. The gas-vessel must then be charged till it lifts this weight. The boats and load will then be slung in their places, and the final adjustment made.

The best preliminary mode of buoying the gas-vessel would perhaps be the following. As soon as it begins to rise the upper link of a chain would be attached to its bottom, just beneath the centre of buoyancy. This chain would be made of links, of each of which the weight is known. The upper links would be large and of great weights, the lower would be smaller, the chain tapering off from end to end. A series of solid weights tied to a rope at intervals in regular order would answer the purpose equally well, and would perhaps be more convenient, as admitting readily of alteration of the weights. The flow of gas would be regulated according as the weights lifted approached the desired point. A spring to be compressed by the rising force of the gas

[1] The envelope will, of course, have been carefully proved before it was introduced into its place. None will be allowed to pass into use before having been subjected to the test in a public proof-yard by the authorised inspectors of the aerial navy.

might be used for the same end, but not so aptly as the weights, for with all springs the sensitiveness must diminish as their tension increases, so that the final increments of buoyancy could not be so correctly observed as the first. The reverse of this is what is required, and such would be the result given by the tapering chain, of which the sensitiveness will be greater and greater towards the end of the operation. Any degree of exactness in adjustment may be obtained by this method. If the wind is blowing during the buoying of the gas-vessel, and the latter has not the protection from it which will generally be provided in the air-ports, the force of the wind must be neutralised during the process by tying the beak of the gas-vessel by a horizontal cord to a ring traversing on a mast or rope stretched vertically. This ring must be kept at the height at which the long axis of the vessel lies. As the latter, lifting the chain, rises, the point of attachment must be shifted up by a cord and pulley.

When at last—the cargo being stowed, the boats slung, the power up, and the last passengers on board—the floatage is brought to the exact point required, the gas is cut off, the power turned on, and the craft starts. But now, notwithstanding the excellence of the envelope, leakage must go on. It is impossible but that there must be a continual, though slow, diminution of the buoyancy by reason of the loss of hydrogen from within the gas-vessel. Another cause of loss of floating power which, though not constant, is one to which the craft will be always liable, is the deposition of atmospheric moisture by rain, dew, or snow upon the vessels. I have already mentioned this source of derangement, as being one against which it is of great importance for the aeronaut to provide. A third varying condition that will be continually causing changes in the buoyancy of the float, and therefore disturbances of the equilibrium, tending to compel the craft to rise and fall alternately, is the temperature of the gas under the influence of the sun, and of the cold of night. During the day the gas will be expanded by the warmth which it will derive from contact with the sides of the vessel that holds it, and its lifting power will therefore be increased. When the sun is down the gas-vessel will be losing heat by radiation, chiefly from its upper part with

which the warmest gas will be in contact, and thus the gas being made to shrink will lose in buoyancy.

It is quite impossible to estimate beforehand what will be the extent of the variations due to these disturbing causes. The result of the first of them will be a constant small increase of the specific gravity of the system; of the second an occasional great increase followed sooner or later by relief; of the third gradual diminution, and subsequently gradual increase, or the reverse, according as the voyage commenced before or after the hour of greatest diurnal temperature. The first of these is more or less in the hands of the envelope maker, and no doubt will, as his department of industry improves, be reduced to a very small quantity. The second too may be diminished, to a great extent, by making the outer surface of the vessels sufficiently repellent of water. The limits of the third will be in some degree narrowed by constructing the outer shell of the gas-vessel of materials which transmit heat as slowly as possible.

It might seem at first sight that the amount of expansion, and of consequent augmentation of buoyancy, which the gas would sustain by the influence of the sun, might be pretty nearly calculated; for we know the mean temperatures for every hour in the year at a great number of places, and we also know exactly how much the gas expands for every degree that it rises in temperature. But there are two difficulties in the way. In the first place we cannot tell how much the temperature of the gas will be increased, when that of the ground, or of the lowest layer of air at the place from which the craft starts, rises any given number of degrees. Secondly, we are still less able to know what will be the temperature of the outer air in which the craft is floating at any given time. It is well known that radiant heat passes through the air without communicating to it any warmth; and that the air derives almost the whole of its heat from the soil, from which, as it is warmed, it mounts upwards, continually losing warmth by converting it into expansive force as it rises. Thus the problem of finding the temperature of the air at any given height under any given circumstances of sunshine, is as complicated an affair as could well be conceived. Again, both the air without, and the gas within the vessel, will both be warmed by

contact with its heated sides when the sun shines upon it. But the gas being enclosed and unable to escape, will accumulate the heat which it thus acquires, while the outer air as soon as it is warmed, being free, mounts upwards, a colder layer falling to replace it. Thus, during the day the contents of the gas-vessel must be warmer than the air without. For similar reasons it will have a tendency to become colder during the night. The buoyancy of the crafts will depend partly upon the difference of temperature between the gaseous fluids on the two sides of the envelope.

However, it must always be borne in mind as a fact, one of the most important for the aeronaut, that whatever may be the lifting power of a charged vessel at any place, it is always the same at any height in the air, setting aside the influence of temperature, so long as the gas has not expanded to a bulk greater than the capacity of the envelope that is to contain it; so that an air-craft whose gas-vessel is half-full, and of which the weight is exactly counterpoised at the ground by the buoyancy of the float, if raised by mechanical force, and then left to itself at any height below that at which the pressure is only one half of what it is at the surface (that is, below the height of about 18,000 feet or $3\frac{1}{2}$ miles above the sea level), will float there in exact equilibrium with the air, without any tendency to rise or to sink. This invaluable property of the atmospheric float is due to the natural law, that the density of all gases is directly proportional to the pressure to which they are exposed.[1] If, however, the craft be raised above this height, at which the gas-vessel will have become fully inflated, some of the gas must escape, and then if the upward propelling force be withdrawn, the whole system must sink down to the very ground.

The provisions then that we require are the means of maintaining the balance of buoyancy, in spite of the disturbing influences which have been mentioned. As to the first of these, the leakage, there are two obvious methods of neutralising its effect. One of these is gradually to discharge weight as the escape of gas proceeds. The other is to supply gas to the vessel continually, so as to compensate exactly the loss which is ever going on. Either of these may be used. The choice of the aeronaut

will be determined upon one or other of them by due consideration of cost and weight. Suppose, for instance, a given gas-vessel to lose, by diffusion through the envelope, a hundred cubic feet of gas per day, and the craft to be starting for a voyage of thirty days, the first question to be considered would be, will the ballast to be carried and gradually expended, namely the weight which three thousand cubic feet of gas would lift, be heavier than the materials necessary to generate that quantity of gas? If so will the cost of the latter be so great as to neutralise the advantage of its levity?

I have before stated my belief that the aerial navigator will never trust to mere ballast as his means of rising in the air; this mode of arrangement implying the waste of gas not only for the purpose of descent, but for that of maintaining the balance of buoyancy, and of preventing the craft from rising too high on each occasion of ascent. However, this application of ballast for keeping the equilibrium constant is a very different matter, involving no waste of gas, but only the use of a certain extra quantity for the support of the additional weight carried; it is therefore quite allowable, and may be most necessary. Now three thousand cubic feet of hydrogen will lift two hundred and five pounds.[1] This then is the weight of material that would have to be embarked at the commencement of the voyage, for the purpose of compensating the slow loss of buoyancy by its gradual discharge as dead ballast. On the other hand, hydrogen is the only gas that would be likely to be used for the purpose of procuring buoyancy under these circumstances, and water is its universal source; if then the loss of buoyancy is to be made good by the supply of fresh gas, water must be carried for its generation. Now 100 cubic inches of hydrogen weigh 2·137 grains; so that three thousand cubic feet of this gas will weigh about 16 pounds;[2] and since water consists of eight parts by

[1] See Table. Appendix F.

[2] 1 cubic foot = 1,728 cubic inches ∴ a cubic foot of hydrogen weighs $\frac{2{\cdot}137 \times 1{,}728}{100} = 36{\cdot}9274$, say 37 grains, and 3,000 cubic feet weigh $37 \times 3{,}000 = 111{,}000$ grains $= \frac{111{,}000}{7{,}000} = 15{\cdot}85$, say 16 pounds.

weight of oxygen with one of hydrogen, 9 pounds of water must be required for every pound of the lighter gas. For the three thousand cubic feet then, $16 \times 9 = 144$ pounds of water must be carried. To this must be added the burden of the materials necessary to decompose the water. If these amount to a weight less than $(205 - 144 =)$ 61 pounds, and are not too costly, it would be better for our air-craft to keep up the buoyancy by supplying the envelope with fresh gas, than by discharging ballast —it would be better to decompose the ballast water than to throw it away.

I shall not here pursue the comparison further, but shall consider how the gas might be conveniently produced in the air-craft for this purpose. Magneto-electricity, or chemical force, must be resorted to. If the former method can be made to act with sufficient vigour in proportion to the weight of the apparatus that produces it, it will be the best mode of evolving hydrogen in the floating air-craft. For no additional weight of water will have to be carried beyond that which is to be decomposed. Besides this, the oxygen which was in combination with the hydrogen being set free, will be available for intensifying the heat in the source of motive power. But further, every pound of hydrogen that is evolved not only adds thirteen pounds [1] to the lifting power of the system, but represents an actual diminution of the load by its own weight together with that of eight pounds of oxygen thrown off. So that in this mode of application the water serves the double purpose of supplying both floatage and ballast for discharge. Every nine pounds of water thus got rid of by decomposition—the hydrogen being passed into the float, and the oxygen liberated—represents a lightening

[1] 2·137 grains of hydrogen at a temperature of 60° Fahr., the barometer standing at 30 inches, measure in volume 100 cubic inches, $\therefore$ 1 pound = 7,000 grains are in bulk, under the same conditions $\frac{7{,}000 \times 100}{2{\cdot}137} =$ 327,565 cubic inches = 189·5 cubic feet. Again, 100 cubic inches of air weigh 30·829 grains, $\therefore$ 327,565 cubic inches of air weigh $\frac{30{\cdot}829 \times 327{,}565}{100} =$ 100,984 grains. The buoyancy then of 1 pound of hydrogen is represented by a lifting force of $100{,}984 - 7000 = 93{,}984$ grains = 13·426 pounds.

of the system equal to that resulting from a discharge of (9+13 =) 22 pounds of ballast. The advantage then of the supply of gas by this method over the rejection of ballast as a means of preserving the buoyancy is not represented by the ratio of 205 : 144 : or of 13 : 9, but by that of 22 : 9. These numbers give the measure of the margin which can be allowed for the weight of the magneto-electric engine for decomposing the water. So that if the weight of the apparatus necessary to decompose the water with sufficient rapidity, does not bear to that of the entire quantity of water upon which it will have to operate a greater ratio than (22−9=) 13 : 9, it will be more advantageous to decompose the water by mechanical power acting on a magnetic mechanism, than to carry the water, or an equal weight of sand, to be let off by degrees as waste. The longer the voyage of course the greater the advantage of the decomposing method, as the mass of the magnet-machine will be a constant quantity, depending solely upon the volume of gas required in a given time, and therefore will not be increased, however the time during which it is to work may be extended. In the weight of the magnet, of course the fuel, spring, or other source of power necessary for driving its armatures must be included. As yet, however, no magnetic arrangement is known of sufficient energy to decompose water for practical use in supplying gas, unless the instrument of M Nollet, patented in this country by Mr. Shepard,[1] can really accomplish all that it promises.

In the case of chemical decomposition of the water-ballast there is this difference, that the oxygen of the water is not given off, but combines with the substance that promotes the decomposition. The process may be conducted either by aid of fire, or at a lower temperature by other means. The red-heat methods which have been already described as excellently useful for the production of hydrogen on the large scale on solid earth, are not well fitted for employment in the air. Firstly, because for the ends we have now in view a slow and perhaps sometimes interrupted or retarded supply of gas is required, and this process involves the use either of large gas-holders, or retorts kept always

[1] 'Mech. Mag.' vol. liv. pp. 362, 410. 1851, May.

red-hot; secondly, because it will always be desirable to avoid the use of fire in the air-craft, except where it is necessary. If the hot method were used in the air-craft, the oxide of iron produced might of course be thrown away, or carbon might be used up in reducing it. In either of these cases the whole advantage would be obtained from the water towards compensating the leakage, with, indeed, the additional diminution of the weight of the fuel by its consumption in the furnace. If, therefore, the objections to its use can be surmounted, this method may be useful for the purpose we are now considering.

However, the cooler or liquid process is most likely to come into use in the air craft. In this case, the oxide of the metal which is the agent of decomposition will remain in solution in the water, and since this will always have a commercial value it will not be thrown away. The water then can only be looked to for its produce of gas, as helping to maintain the buoyancy of the system. The weight of the substances which will be used for decomposing the water, and of the apparatus for conducting the process, will have to be taken into account in making the comparison with ballast, on the score of economy of weight. The weight too of water, necessary to combine with and to dissolve the products of the operation, must also be reckoned.

The usual chemical processes for the evolution of hydrogen from water, are the addition to it of sulphuric or hydrochloric acid, and either metallic zinc or iron. It may be useful to enquire what are the smallest quantities of water that can be used with effect in this method, and the weights of the materials that must co-operate with it to produce a given quantity of hydrogen.

In the zinc process, for every equivalent of hydrogen that is evolved, one of sulphate of zinc is formed. This salt must be kept in solution, so that it shall not, by settling on the metal, impede the continuance of the reaction. Now this salt has the property of solidifying seven equivalents of water by crystallisation, and this hydrated salt requires a quantity of water nearly equal in weight to itself to dissolve it. So that every pound of hydrogen which is produced involves the use of 289 pounds[1] of

[1] The result of the operation being represented in symbols, thus: $H + ZnSO^4 + 7\ HO$, and the equivalent numbers of the elements concerned

materials, on the supposition that at the end of the operation nothing is to remain behind but a cold saturated solution of sulphate of zinc in water. In practice certain circumstances would occur which would modify the results in some degree. For instance, if the metal were suspended in the upper part of the acid liquor, the saturated solution of sulphate, being thus allowed to fall at once to the bottom of the vessel as soon as formed, might crystallise out without being kept in solution; and thus the quantity of water necessary to be carried would be diminished. On the other hand, the metal will contain impurities, and an excess of all the ingredients in the process must always be carried to meet emergencies. Besides this, some water would be continually carried off from the vessels by evaporation, and so, unless condensed before reaching the gas-vessel and returned to the apparatus, would be lost for the purpose of making hydrogen. The quantity above stated, or nearly 300 pounds, may be taken as not greatly overstating the weight of materials, exclusive of apparatus, that must be carried to generate 1 pound of hydrogen, which as has been shown above will do the work of only 13 pounds of waste ballast. It would appear then that the plan of rejecting superfluous weight is far more saving of power than that of keeping the floatage continually up to its original strength. If iron be used instead of zinc, the conditions are but little altered[1] as respects the ratio of the buoyancy to the weight of material necessary to produce

being as follows: H, 1; O, 8; S, 16; Zn, 33, the sum of the weights of the substances concerned in the production of each equivalent of H, are $1+33+16+32+7+56=145$. For every pound then of hydrogen that is evolved, 144 pounds of crystallizable sulphate of zinc remain behind, and these require 0·923 parts ('Gmelin's Handbook of Chemistry,' 'Watts's Eng. Tr.' vol. v. p. 26), that is, practically, 1 part by weight of water for their solution at the common temperature. So that the weight of the residual saturated liquor must be 288 pounds; and before the decomposition commenced, the hydrogen being then in the liquid, 289 pounds of material must have been present.

[1] The equivalent weight of iron being 28 instead of 33, which is the number for zinc, the sum of the weights of the ingredients is reduced by 5 units, that is to 140. The resulting sulphate of iron takes up, like the zinc-salt, 7 equivalents of water in crystallising, but it requires more water for its solution than does the sulphate of the other metal.

it. That I have not here overrated the weight of the water necessary to the metal acid process may be inferred from this. The proportions of the ingredients which are commonly recommended to be used for preparing hydrogen are equal parts by weight of the metal and acid, and about five parts the weight of water. These give a total of 343 pounds of ingredients for a pound of hydrogen.[1]

If hydrochloric acid be substituted for the sulphuric, the conditions as respects the weight of the materials will not be much improved. For every pound of hydrogen will require, as before, 33 pounds of zinc or 28 pounds of iron to be carried, together with 273[2] pounds of aqueous solution of hydrochloric acid,

[1] The equivalent number of zinc being 33, and that of sulphuric acid (oil of vitriol) 49, equal weights of the two will leave an excess of metal, which is a prudent provision to avoid waste of acid. The acid, therefore, must be taken as the standard, as the whole of it is supposed to be consumed. The quantities then required according to the practical rule for 1 pound of hydrogen will be 49 pounds of oil of vitriol, 49 pounds of zinc, and $5 \times 49 = 245$ pounds of water; total 343. In the formula which I have given, the water is computed at 7 equivalents, together with a quantity equal to the weight of the resulting crystallisable salt $= 7 \times 9 + 144 = 207$ pounds, for the pound of hydrogen, corresponding to rather more than four parts by weight of water to one of acid and one of metal.

[2] The equivalent number of chlorine being 36, that of gaseous hydrochloric acid is 37, and to keep this acid in solution at the common temperature and pressure, at least 6 equivalents of water are required. The strongest liquid hydrochloric acid that can be made by saturating water with the gas, namely that of specific gravity about 1·2, containing 40·6 by weight of real acid for every 100 parts of liquid, the equivalent of the concentrated acid will be $\left(\frac{37 \times 100}{40 \cdot 6}\right) = 91 \cdot 1$. Now $91 - 37 = 54 = 6 \times 9$, thus, 9 being the equivalent number of water, there are 6 chemical parts of water in the acid. Since both the chloride of iron and that of zinc, the latter especially, are extremely soluble in water, this quantity of liquid might be sufficient for keeping the metal free from salt, by removing the latter as fast as it is formed. But heat arises from the chemical action, and the acid gas will be thereby volatilised and lost, unless a further quantity of water be added for the purpose of moderating the energy of the decomposition, and of keeping the acid in solution. Accordingly it is generally recommended to dilute the hydrochloric acid with 2 parts by weight of water. The equivalent weight then of such dilute acid would be $3 \times 91 = 273$.

making in all 306 or 301—say 300—pounds of substances for producing the gas. To this must be added a certain quantity of lime and water for purifying the hydrogen, for in this case we are dealing with a volatile acid, and it will be particularly important to wash the gas well on its way to the float, lest it should be contaminated with vapours that would be injurious to the envelope.

As a general rule, then, it will be better as involving a smaller additional burden, and therefore a smaller quantity of gas at starting, to adjust the buoyancy by discharging ballast, than by producing hydrogen according to either of the modes of chemical decomposition that are ordinarily adopted or recommended. But there is another mode of producing hydrogen, well known to chemists, which seems to have entirely escaped the notice of engineers, and of the devisers of technical applications of chemistry to the purposes of life. This is the evolution of the gas from water by those metals which can effect the decomposition of the liquid without the aid either of acid or of heat. These are potassium and sodium, which will be the gold and silver of a future age, when the wealth of all, not the richness of a few, shall be the aim and glory of human kind. Polar indeed to the glittering toys of Mammon, which in the pride of beauty and selfishness spurn the attachment of oxygen, these truly precious metals eagerly claim the natural union which is the due of all things, and in receiving it do a mighty work for the help of man in subduing earth.

Of the two metals of the alkalies that are soluble in water, sodium is the best for our purpose, for several reasons. Firstly, its equivalent weight is less than that of potassium, their chemical numbers being respectively 23 and 39. Secondly, the alkali, which is its source, is the cheaper and more plentiful of the two, the price of 'soda ash' being considerably less than half that of crude carbonate of potash. Thirdly, the process of reducing the sodium is more easily conducted than that for potassium, for the former metal is more volatile, and therefore more readily distilled than the latter. Fourthly, the process is more productive of sodium than of potassium, since sodium if reduced with charcoal does not waste itself by combining with the carbonic oxide, as

does potassium. Fifthly, this process is less dangerous, for there is no explosive compound formed by sodium under this treatment. Sixthly, though sodium decomposes common cold water quite as rapidly as can be desired for any purpose, the reaction is less furious than that of the other metal, and its use is not attended with any danger of conflagration, since the heat produced is not sufficient for the ignition of the hydrogen which is evolved, if the metal should come in contact with water in the presence of air. I shall therefore take sodium as the special subject of my remarks in this matter.

'Should sodium,' says Professor Gregory, 'be ever required on the large scale, it might be obtained for a price little, if at all, higher than that of zinc.'[1] There can be no doubt that this will be accomplished; if we did not require this substance for furnishing us with hydrogen for heat and light, and for decomposing the oxides of still more refractory metals, aerial navigation would perhaps create a demand for it. All the sodium in the world, which is now sold in miserable little globules at the rate of a shilling a grain, is made in pocket retorts in two or three laboratories on the Continent. England will have to show the world what her seas and her coal can do in administering by this vast neglected power to the wants of humanity. Sea-water contains about 27[2] grains of common salt, and therefore about 10 grains of sodium,[3] in every 1,000 grains of liquid. Every 10 gallons, then, of water in the seas that wash our shores may be considered as containing at least a pound[4] of sodium—a sufficiently large store for any purposes we can put it to. Now all that is necessary for the obtainment of this metal from the crude carbonate of soda, produced by the usual process from the salt, is to mix it with charcoal and to heat it to a high temperature.

[1] 'Outlines of Chemistry,' p. 150.

[2] Graham's 'Elements of Chemistry,' 2nd ed. vol. i. p. 319.

[3] Equivalent of sodium, 23; of chlorine, 36 : $36+23=59$; 59 : 23 :: 27 : 10·52.

[4] A gallon measure contains 70,000 grains of pure water; supposing then that it held no more sea water than this, ten gallons measured would weigh 700,000 grains, and will contain 7,000 grains = 1 lb. avoirdupois of sodium, which will decompose 9 lbs. (1 gallon nearly) of water.

The process will be best conducted in fire-clay retorts.[1] The distilled metal will be received and kept in hydrocarbon oil from coal tar, carefully purified from substances containing oxygen. This liquid is better for the purpose than earth naphtha, as being much cheaper, and than oil of turpentine, as not being liable to absorb oxygen from the air.

The metal sodium decomposes water at the common temperature, setting free pure hydrogen. We must enquire whether, among the uses to which this faculty may be applied, that of aiding the failing buoyancy of gas-vessels can be reckoned. Twenty-three pounds of sodium are required for the production of one pound of hydrogen. This quantity will decompose nine pounds of water, combining with the eight pounds of oxygen and setting free the other gas. The oxide of sodium thus formed seizes inexorably on another equivalent of water to form the hydrate of soda; and this alkali requires for its solution a certain further quantity of water,[2] 66 pounds, it would appear. The entire quantity, then, of material necessary for producing 1 pound of hydrogen will be—Sodium, 23; water, $18+66=84$; altogether, 107 pounds. This gives a very great advantage over all the acid processes, the most favourable of which would require at least 300 pounds to be carried to produce a pound of the gas, which would amount to 189 cubic feet in bulk, and would support 13 pounds. No doubt by an appropriate arrangement the necessity of keeping the saturated solution of the alkali might be avoided, and thus the weight would be very much diminished.[3]

[1] Instead of little iron mercury bottles, which necessitate the use of pure carbonate of soda containing no sulphate (for this being reduced by the carbon to the state of sulphide attacks the metal), fire-clay retorts lined with charcoal must be used. These will be far more durable than iron ones, and will admit of the use of crude carbonate of soda.

[2] 100 parts of water at 18° Cent. dissolve 60·53 parts of hydrate of soda (Gmelin's 'Handbook of Chemistry, Watts's Eng. Tr.' vol. iii. p. 76). Now our hydrate of soda corresponding to the 1 lb. of hydrogen weighs $23+8+9=40$ lbs. These, therefore, just saturate $\frac{40 \times 100}{60{\cdot}53}=66$ lbs. of water.

[3] For, instance, the sodium might be acted on by steam from a boiler, part of which it would decompose, while another portion being condensed

But under the most favourable conditions, the ballast plan would be far more economical.

Unless, then, means can be found of decomposing water by magneto-electricity or otherwise, with far greater energy than can be done by any means we at present possess, we may be contented to adjust the burden to the gradually diminished buoyancy of the gas-vessel by rejecting weight.

Dry sand or water, then, will be carried for this purpose, and will be placed in a vessel from which it is allowed to run out slowly, by an aperture beneath the centre of balance of the boat. During long voyages at great height in the air, the water would be liable to freeze, sand therefore in such cases would be preferable. The ballast vessel must be so arranged, that by the simple movement of a valve the discharge of its contents may be stopped, started, or regulated at will. In large and very completely fitted air-craft this apparatus may be made self-governing when desired, by connecting the valve with an electro-magnetic apparatus, regulated by the movements of the index of an aneroid barometer, or with a horizontal vane, which should receive the resistance of the air on its upper or under surface when the system is rising or falling. Such self-adjusting mechanism must however, of course, be thrown out of gear whenever the craft is intentionally raised or lowered; it can only be of use when the required course lies at a certain unvarying height in the atmosphere.

The second kind of disturbance of the balance of buoyancy, that of great sudden increase of the load, must now be met. There are two obvious modes of neutralising this inconvenience; either an equivalent weight of ballast may be thrown overboard, or the propelling power of the craft may be taxed for the resistance of the downward pressure. If the first of these is to be resorted to, a quantity of extra ballast must always be carried, equal at least to the weight of the greatest quantity of water that can adhere to the craft. In case of a wetting, ballast must be discharged so as to adjust the balance, and afterwards, when the

and dissolving the alkali formed, would run back to the boiler, where the soda would remain, the water being evaporated off as required by decomposition.

moisture is removed by evaporation, the propelling power must be made to resist the upward traction of the relieved gas, and the voyage must be continued thus, of course at a diminished speed, until an opportunity offers of descending to the earth, and of taking in fresh ballast.

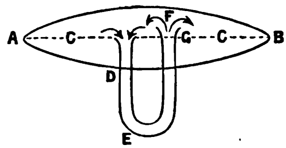
I shall reserve what I have to say about the application of the driving power to the adjustment of the buoyancy to the next chapter, in which the same principles are involved. Of course, instead of taxing the regular propelling power for this service, a special mechanism, fitted with wafts acting in vertical planes, may be provided for this particular end.

Finally the gradual nocturnal decrease, and diurnal increase of lifting power in the float claim attention and adjustment. These disturbances may of course be reduced to uniformity by alternately rejecting ballast and gas. If this plan be followed, the vessel must be loaded at starting with a great quantity of extra dead weight, which must be thrown off by degrees when the gas shrinks with the cold, while, when the heat of the sun expands the gas again and restores its buoyancy, a due portion of it must be discharged, to prevent the craft from rising. This device might be adopted for short voyages of a night or two. But I shall not recommend it for the traffic to Hong Kong or New Zealand. I have not yet provided our gas-vessel with any means of discharging gas, having abstained from suggesting a valve; in the next chapter I shall introduce the apparatus which I would propose to use for this end when it may be necessary. These daily variations of buoyancy will be occasioned by changes of temperature; the simplest mode of compensating them will be by converse alterations of this same condition. We may take the greatest dilatation to which the gas is subjected during the course of the day as its standard state; if then, as by decline of the natural temperature, its buoyancy falls off from the degree due to this its greatest volume, we can warm it artificially to the same extent, the required end will be obtained. It is to be observed, too, that this warming of the gas-vessel during the night will oppose at the same time another agency which will be tending at that time to diminish the buoyancy of the craft. This is the deposition of dew on the

vessel, which, coming simultaneously with the shrinking of the gas with the cold, will greatly aid the former cause in deranging the due balance. This condensation of moisture on the gas-vessel will be prevented by keeping its contents warm, and thus its surface will be above dew-point of the surrounding air.

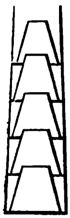
Now this may be very easily accomplished, either by heating directly the gas which is within the envelope, or the air which, the gas-vessel not being full, occupies the space between the lower surface of the envelope and the outer shell. The mode by which the heat may be communicated is extremely simple, being the same which is frequently applied to supplying warm air to rooms and buildings. It depends upon the elementary principle that heated air ascends, and cooler air falls, whenever they are free to set up a mutual circulation. This principle may be applied to the regulation of the temperature of the floating gas-vessel, by means of the following apparatus. Let A B (fig. 134) be the gas-vessel, C C the lower wall of the envelope, forming the diaphragm between the gas and the air within the vesssel, D E F a siphon tube opening into the envelope at D, the mouth of its shorter limb, and, of course, in air-tight connection with it at that point, at which it forms, as it were, a neck to the envelope. Let the other limb F of the tube pass, air-tight, through the envelope as at G, and let it be continued, as at G F, nearly up to the roof of the vessel within, the mouth F being open to the gas, and suspended from the top of the envelope. If now the mouths D F of the tube be kept open, and there be a free passage through its whole length, any heat that is applied to the bottom of the long leg will cause the gas that lies there within it to expand and rise to F, where, escaping, it will spread itself over the upper part of the vessel. Meantime the colder gas from the bottom of the envelope will flow down through D to E, and, being heated there, it will rise again through E G F to the top. A circulation of the gas will thus be established, by means of which the contents of the envelope may be heated to any required degree, and the buoyancy adjusted

Fig. 134.



with precision. In the construction of this circulating tube, several points will have to be attended to. Firstly, the whole of that part of the tube that lies within the gas-vessel must admit of contraction and extension of its length without considerable alteration of its calibre, or, at least, without obstruction to the channel through it. Secondly, the mouth D must be so arranged that it can never become closed by folds of the envelope, whatever may be the changes in the expansion of the latter. Thirdly, the tube must resist compression from without, so as to retain its cylindrical shape; for, if not so constructed, its sides will be squeezed together by the air, and the gas will all be forced out of it into the envelope above. Fourthly, the whole tube must be perfectly gas-tight, and especially the limb E F must not be liable to injury by the heated gas in its passage through it. Fifthly, the part of it at E to which the heat is to be applied must be of metal, so as not to be injured by the heat, which it must transmit readily to the gas within. It would probably be made of oil-varnished linen, or of vulcanised caoutchouc lined with strong unvarnished cloth, and kept in form by hoops within it at regular short intervals. In the part within the gas-vessel these hoops would be replaced by cones of light thin wood, or of metal plate, fitting within each other, and attached to the tube at their lower borders as in fig. 135. These cones would keep the tube open, at the same time that they allowed it freely to contract or extend its length. They would also protect the tube from the hot gas. The regular contraction and extension of the tube might be further secured by uniting the lower border of each cone to those above and below it by two or three elastic bands of vulcanised caoutchouc, if the tube were made of inelastic material.

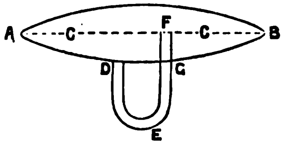
Fig. 135.



The functions, however, of this apparatus for directly heating the hydrogen may be more simply, and perhaps as efficiently, fulfilled by heating the air beneath the envelope within the gas-vessel in the same manner. The arrangement for effecting this is represented in fig. 136, in which the same letters refer to parts similar to those in fig. 135. The part G F of the long limb alone

will, in this case, require to be extensible; it will, of course, be slung to the lower surface of the bottom of the envelope. The heated air, ascending through E G F, and spreading itself along under C C, will warm the envelope and the gas within it, while the expansion of the air itself will aid the purpose of exalting the buoyancy of the system.

Fig. 136.



The metallic segment of the tube at E in either case will, of course, lie in the man-vessel, where it will be heated by lamps.

Instead of heating the atmosphere enclosed within the tube and gas-vessel by heat applied without the former, the space between the lower sides of the envelope and gas-vessel may be made to serve the purpose of an ordinary Montgolfiére, by supplying it with hot air from the heater-lamp itself. If this plan is adopted, the circulating apparatus will be reduced to a single tube forming a neck to the gas-vessel, open below, and having the lamp burning at its aperture. This will be a far simpler device, and more economical of heat; but two points must be considered: Firstly, all the products of combustion from the lamp will be carried up into the gas-vessel, and the water which forms a part of them will be deposited within it: this unnecessary moistening of the interior of the gas-vessel may be productive of inconvenience. Secondly, though the danger of directly igniting the vessel by the flame of the lamp will be nothing at all if the apparatus is properly constructed, yet an explosive atmosphere might be formed beneath the envelope by the escape of gas from within, and the contact of this with the flame might be productive of disaster. If, however, the whole atmosphere within the gas-vessel is cut off by direct contact with the ignited fuel, this danger would not arise. This same mode of heating may of course be applied to the expansion of common air, without the aid of hydrogen. If the heat were thus applied to metal tubes considerably below the vessel itself, a much larger fire might be used, without any danger of igniting the envelope. The circulating tube being laid within a closed furnace, and passing up

within its chimney, so as to obtain the greatest quantity of heat, it is probable that a higher degree of expansion could be obtained than by any other method.

Every adjustment of the buoyancy may of course be effected by a judicious combination of a special separate hot air-vessel with a hydrogen float. It is, indeed, extremely likely that this method will be adopted in some of the heavier slow-going craft, but the additional resistance of the air to the double surface of the two vessels will not admit of its application to the purposes of rapid transit. In the vehicles for swift passage, the several causes of variation of floating power must be combated by some such methods as those which I have here suggested.

To the causes which I have above mentioned, as tending to derange the balance of buoyancy in all air-craft floated by gas-vessels, may be added another, which will affect them under certain circumstances. This is a regular continual increase of the floating power of the system, arising from the consumption of fuel, in case of heat being used as a source of power, and from the loss of vapour, if water or other volatile matter be consumed in the engine. The gradual diminution of the burden by both of these losses of weight must be considered. The inevitable result of this process of combustion and evaporation must be a constant addition to the force tending to lift the craft from the earth. This will be to a slight extent compensated by the leakage of the gas. Any excess of buoyancy can only be neutralised either by rejecting gas, or by using a part of the propelling power in opposing the upward traction of the float. M. Monge has actually proposed to prevent the gradual loss of weight of the fuel by passing the gaseous products of combustion through an apparatus charged with milk of lime, and so condensing the carbonic acid.[1] If he had taken the trouble of calculating the weight of material necessary to be carried for such purpose, he would scarcely have ventured to make such a suggestion. For every pound of fuel to be consumed would involve the necessity of loading the boat with at least five pounds weight of milk of lime.[2] And this does

[1] Monge, Etudes, pp. 87, 136.

[2] Whatever the fuel may be, a quantity of carbonic acid considerably greater than an equal weight will be produced by its combustion, for all

not include the weight of the apparatus for containing it, and does not provide against the evaporation of the water—which, it must be remembered, will amount to about five pounds for every pound of fuel burned.[1] Either all the steam must be so much weight lost, or it must be condensed. In very large craft condensing engines may be used, but in smaller vessels the weight of the condensing apparatus cannot be carried, and the steam must escape.

In this case, if the voyage be a short one, the horizontal course of the craft will be best preserved, under these circumstances, by starting with less gas in the vessel than is sufficient to counterpoise the burden, and by making the propelling power do a part of the work of lifting. As the voyage continues, and the feed of the engine is used up, the buoyancy will gradually increase, till it is in equilibrium with the weight, and will finally be in excess. The driving power will then have to contend partly against the upward traction of the gas. Thus the maintenance of the elevation of the craft will depend upon the gradual change in the direction of the moving force; and this will be best effected by a regular adjustment of the angle at which the

the carbon in the fuel produces if thoroughly burned $\frac{22}{6} = 3\frac{2}{3}$ times its own weight of carbonic acid, and no substance containing less than 80 per cent. of carbon would be likely to be used for fuel by the aeronaut. The combustion, then, of a pound of any such fuel would generate at least $\frac{80}{100} \times \frac{22}{6} = 2{\cdot}9$ lbs. of carbonic acid. To replace the weight of a pound of fuel, a pound of this gas must be absorbed. Now the equivalent number of the solid hydrate of lime is 37, and that of carbonic acid 22. A pound of the gas, therefore, would require $\frac{37}{22} = 1{\cdot}7$ lb. of the hydrate of lime for its absorption. But the condensation of the gas cannot be ensured unless it be passed through the lime mixed with water. Now a sufficiently liquid emulsion of the lime cannot be made with less than three times its weight of water. This will make it necessary to carry $3 \times 1{\cdot}7 = 5{\cdot}1$ lbs. weight of material for every pound of fuel.

[1] $4\frac{1}{2}$ lbs. coke evaporate 2 gallons of water (Armstrong, 'Treatise on Steam Boilers,' p. 3, 1851), 2 gallons water weigh 20 lbs. This gives the ratio of the weight of the water to that of the fuel as $20 \div 4{\cdot}5 = 4{\cdot}5$. But in aerial steam-engines the very utmost of evaporation would be extorted from the fuel by the most perfect contrivances for saving it, so that at least 5 may be taken as the equivalent weight of the steam, that of the fuel being 1.

kite-plane is set. The use of this apparatus will be further treated of in the next chapter.

If, however, the voyage be a very long one, without the opportunity of descending to take in fuel and water, the compensation may be more easily effected by allowing gas to escape from the vessel as the weight which it has to carry is diminished. Thus, every pound of fuel that is burned being accompanied by the evaporation of five pounds of water, represents a diminution of the weight of the system by six pounds, and would require the rejection of about eighty-seven cubic feet of hydrogen.[1] In the next chapter I shall speak of the means of discharging gas from the vessel in general. Such an apparatus might be directly connected with the engine by an adjustment which should regulate the discharges of gas according to the requirements of the system, while it maintained its general relation to the consumption of power-stuff about the ratio just indicated. But for the present purpose this will be effected in a different manner. During a long voyage, this requirement of the balance of buoyancy may be best met by keeping the course of the craft at such a height in the air, that the gas-envelope is always completely full. By this method the balance of buoyancy will be made self-regulating. For, as soon as it is disturbed by a diminution of the weight of the system from loss of fuel and water, the craft will rise; but if the gas-vessel be full, it cannot rise ever so little without some gas escaping, and the buoyancy being diminished. The tension-valve of the envelope will open, and allow the discharge to take place until the expansion of the gas ceases. Meantime, the diminution of the weight of the burden has been going on: the craft does not therefore descend, as it would if otherwise any of the gas had escaped while the burden remained the same. The result of these self-compensating variations of the quantity of load and of gas will be, that the craft will proceed steadily at such a height that the gas-vessel is always full. If it should be necessary, for the purpose of clearing the Himalayas or the Andes, or of taking the upper trade wind, to rise to a greater height in the air, this can only be accomplished

[1] See Appendix F.

by having the air-craft provided with two envelopes within the gas-vessel. The lower of these must be empty at starting, and must remain so as long as the craft is below the level at which the upper one becomes full: the latter must communicate with it by a separate tension-valve, opening outwards from the upper, inwards to the lower vessel. Means must be provided for locking either of the spring-valves, so that either one or the other, as may be desired, may yield to the pressure of the gas. If it be requisite to rise, the master of the gas-vessel will, by service-cords, release the communicating-valve, and stop the discharge-valve. The pressure of the gas will now find vent only into the lower envelope, and thus, its lifting power still being available, the craft will be able to mount. By reversing this arrangement of the valves, the craft may be made to keep its way at any required height above that at which the upper envelope becomes full. This provision of the double gas-bag may be most important for the economy of the larger air-craft. The same end will of course be equally well served by a single envelope, fitted with an internal diaphragm and two tension-valves, the one in the diaphragm opening downwards, the other connected with the bottom of the upper compartment, and opening outwards to the air.

By this contrivance the craft, notwithstanding the perpetual loss of weight, may be made to travel constantly at any required height, if not without any variation, at least without any greater change than an occasional oscillation above and below a mean altitude. Loss of gas is, in this case, unavoidable; but it must be observed that it is not against all and every discharge of gas that I have protested, but against waste of it, and especially against the dissipation of it for the mere purpose of sinking in the air. Hydrogen is to be the aeronaut's trusty servant, not his idol.

CHAPTER XII.

CONDITION 10.—THE CRAFT MUST BE ABLE TO RISE AND FALL WITHOUT WASTE OF BUOYANCY OR OF WEIGHT.

In the last chapter the attention of the reader was called to the important fact that the height at which the air-craft is moving or lying may be altered without altering its balance of buoyancy, so long as the gas-vessel is not quite full. I have there also endeavoured to show how the craft may be prevented from rising or falling, and from obeying the impulses of any disturbance of the balance of its floatage. I have now to show how, taking advantage of the property just alluded to, the system may be compelled to rise or fall at will, without permanently affecting the equilibrium between the levity of its gas and the gravity of its burden, and without discharging any of either of these fundamental elements of its organism. The first requisite, then, for the fulfilment of this condition is, that the envelope must be sufficiently capacious to contain the whole of the gas which is required for the floatage of the system in its expanded state, at any height to which it may be necessary to rise.

Now, it may be requisite to change the elevation of the air-craft, either gradually in a slanting course, or suddenly in a nearly vertical line. The former will be the every-day occurrence of ordinary navigation in leaving, or descending to, port, in sweeping over tree-tops or mountain ridges, and in seeking calm air, or a current flowing in a certain direction, when the wind is adverse, at the height at which the previous course may have been held. The latter will be an occasional resort upon emergency of danger.

For the gradual ascent or descent, the propelling power of the system will be sufficient. By appropriate arrangement of the appliances of flight, the moving force may be made to act directly

upwards or downwards, and thus a vertical direction may be taken. But usually a slanting line will be followed: this will be effected without altering the position of the propellers, and without working other wafts than those which promote the headward flight, by simply resolving in an upward direction a part of the resistance offered by the air to the forward motion. I have already shown that this must not be done by means of a bird-tail;[1] for very slight and gradual inclines alone is this allowable. This service will, however, be performed by a part of the organism of our craft which has been described already, the kite-plane. I have shown, in discussing the question of anchorage,[2] how this apparatus, being attached to the craft so that the resultant of the forces acting on it shall pass through the axis of balance of the boat, will enable the wind to keep the moored vessel lifted from the earth. It is evident that the very same instrument will enable the system to mount or descend steadily, and without deranging its balance of level, when it is propelled against the air. The angle at which the kite-plane is set will, of course, determine the inclination of the upward or downward motion. During regular horizontal flight, the kite will lie perfectly level, offering only its edge to the resisting air. As soon as it is desired to ascend or descend, its fore end will be drawn up or down, so as to throw it into such an angular position as, by the pressure of the air upon its surface, will produce the required course. It serves, in fact, as a rudder, arranged and acting in a peculiar manner.

The same apparatus will answer a further purpose, which may here be mentioned, as it will sometimes be most important. It will occasionally be requisite to stop the motion of the air-craft somewhat suddenly: for instance, if an obstacle, previously unseen, suddenly presents itself, or on coming to anchor in peculiar localities. No contrivance could accomplish this more effectually, and with so little danger to the safety of the system, as can the kite. To stop suddenly a high-class air-craft, when in rapid motion, would, by reason of the great momentum of so large a mass of matter, be extremely difficult, and, if done quite suddenly,

[1] See p. 77, above.
[2] See figs. 379, 380.

very dangerous. Besides, by any ordinary means, even with the help of an elastic cable to neutralise the shock, it can only be done when the anchor has hold. But with the large kite-plane it becomes a very simple process. All that is necessary is to throw the kite into the position at right angles to the line of motion: it will now receive the direct resistance of the air on its whole surface, and will thus oppose to the progress of the craft a new force, which will be proportioned to the necessities of the case, and which, being derived from the elastic air, will inflict no shock upon the system.[1]

[1] This kite-plane will be one of the most important agents in aerial navigation, not only in the full equipment of such vessels, as it is the special object of this book to propose, but as forming that particular organ of the system, which by its gradual development may alter the whole character of the craft. It is through the use of this apparatus that the transition from the propulsion of gas-vessels to mechanical flying must be effected. By gradually reducing the size of the gas-vessel and increasing the area of the kite-plane, the latter may be made to take the place of the former in the function of sustaining the burden. When men have acquired skill in the management of buoyant vessels, and in the execution of the manœuvres of flight, they may begin to diminish the amount of their statical floatage, and to trust for their sustainment to the dynamical efforts of their muscles or of their machinery. The experiment may be easily and safely tried, of endeavouring to raise from the ground and to navigate a large kite, suspended from a gas-vessel of just sufficient levity to lift itself and the plane, but not the burden attached to the latter. This I believe to be the true mode of attempting mechanical flight, and it seems strange to me that I have nowhere met with the suggestion. Mr. Henson's 'aerial ship' relied for its sustainment on large inclined planes affixed to the sides of the vessel. But not only would the weight of these be an enormous tax on their own resistance, and on the propelling power, but their position so low down in the system—but little, if at all, above the centre of gravity—would render the equilibrium of the whole unstable in the extreme. Mr. Bell's 'parachute motor machine,'* of which there was a model in the Great Exhibition of 1851,† and which was ticketed with an intimation that its clockwork would lift it and propel it through the air, but not that it had done so, is so far an improvement on Mr. Henson's, that the sustaining membrane is raised considerably above the centre of gravity. But this arrangement involves the use of rigid masts, to keep it elevated in the air before the full speed is attained, which would be a great inconvenience.

* 'Patent Journal,' June 16, 1849, p. 93. † Official Catalogue, class 8, No. 14.

The kite-plane then will be sufficient for all the ordinary purposes of altering the elevation of the system in the air, of leaving port, of sweeping over terrestrial obstacles, and of stooping from cloud to land without any alteration of the balance of buoyancy. The same instrument, by modifying the effect of the propelling power, may be made to serve the end—sought in our last chapter—of maintaining the height in the air when this balance may be disturbed.

We have now to provide for the more sudden and singular occasions of rise and fall. The first of these that may occur is on leaving harbour for the voyage. Now, it will frequently happen that, from the peculiar position of the harbour, or on account of some wind or other, there may be a difficulty in rising by a gradual slope in the required direction. If the vessel is furnished with means of propelling itself directly upwards, it may of course start in a perpendicular course. If, however, it have no vertical propellers, it may be useful, if gas be plentiful and the voyage be a long one, so that the sacrifice of gas is inconsiderable in respect of the amount of work done, to throw into the gas-vessel a quantity of gas more than sufficient to counterpoise the burden, so as to lift it at once with the rapidity and to the height

The height, again, at which it is held above the boat, and on which depends the stability of the balance of the system, is necessarily limited by the length of these masts. If, however, the kite or parachute is floated by a gas-vessel that will just lift it together with the ropes which connect it with the burden, the latter may be slung at any distance below it, so as to

Fig. 137.

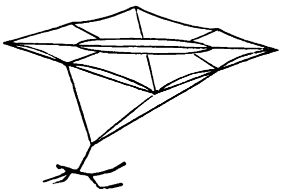
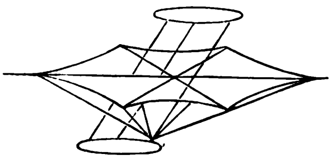


Fig. 138.



give the greatest security against the upsetting of the system. The plane may either be hung from the gas-vessel, or the long axis of the latter may lie within the expanse of the former. Figs. 137, 138, represent these forms of apparatus for flying man and for boat respectively.

that may be desired. When the elevation at which the voyage is to be continued is reached, the superfluous gas would be discharged, and the craft, being now balanced with the air, would proceed on its proper course. The mere overcoming the inertia of the mass of the system on starting from rest will be a great saving of the available power carried in the boat.

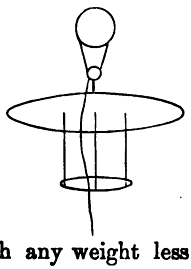
A more economical mode of effecting the first ascent will be to haul the ark up into the air, by the power of a stationary steam-engine. One of the great problems of the aerial navigator will be to get as much of his work as possible done at home on earth, so as to relieve his floating-vessel of power-burden to the utmost extent. This matter forms a part of the subject of a future chapter: the end here sought comes, however, so far under the same head as to involve a reference to this principle. If the craft can be lifted a few thousand feet at the commencement of its voyage, without taxing its own resources, by work done upon the earth, it will be so much clear gain to the aeronaut.

Perhaps the reader may not comprehend at first sight how a stationary engine on dry land can be made to haul anything up into the air to any required height above it. Nothing, however, is simpler. The regular air-port will be provided with tug-balloons, for service exactly analogous to that fulfilled by the steam tug-boats in our rivers and harbours. These balloons—real balloons, made spherical, that their lifting power may be at maximum—will be kept in readiness to lift the starting air-craft to the altitude required for the voyage. When the services of the gas-tug are to be used, the outward-bound air-craft will first be properly balanced. The tug will then be attached to the middle of the top of the gas-vessel, exactly over the centre of gravity of the craft, by a single link, furnished with a trigger, which can be pulled by a cord running down to the man-vessel below. Or, for greater security, the balloon-tug will have a car slung to it, which will carry a man, who will have the command of the tow-links, and with whom the captain of the air-craft will communicate by the magnetic telegraph. To the balloon will also be fixed one end of a strong rope, the other end of which is fast on the ground. The use of this line is for the stationary engine to haul the balloon home when it is cast off by the sailing-

craft. It will be prudent to attach the balloon to the gas-vessel by a second strong elastic cord of considerable length, having also its lower end hooked to a trigger-link tied to the top of the gas-vessel. The purpose of this safety-rope will be to catch and sustain the craft, if, when the balloon is cast off from the first attachment, the craft should begin to fall, from some change or error in its balance of buoyancy. If all is found right, the second tow-line may be cast off by pulling the trigger: if, however, the barometer in the air-craft rises as soon as the first line is freed, the balloon must be warped down again to the craft, and a sufficient quantity of gas to give the required buoyancy to the latter must be pumped from the former into the travelling gas-vessel. When, on further trial, the balance is found correct, the tug will be finally cast off, and will be hauled down to earth again by the engine. The tug will then be ready to tow up another air-craft: or, if it is not required for this service, its gas will be returned to the metal gas-holders of the establishment.

Since the balloon, in rising to any altitude, must exert the same amount of force that is required to pull it down through the same distance, and since it gives out in a second ascent the same power which is put into it, as it were, by the engine in dragging it down, the engine below may be said to do the work of lifting the balloon's burden into the air. The air-craft and balloon-tug ascending together are represented in fig. 139. These captive gas-vessels will also be of the greatest use in carrying up mooring-lines to vessels coming to harbour, and mail-bags and passengers to those that merely touch in passing, and, when the art of navigation of kites and parachutes is perfected, in giving a fair start to the flying machine at the commencement of the journey. If a buoyant balloon be kept moored at any height in the air with any weight less than that which will balance half the free lifting-power of the gas, it may be hauled directly upwards by the fixed engine below, by means of a long cord, and a pulley-wheel suspended to the balloon, without pulling the balloon down. For numerous reasons, however, the former mode of application will be pre-

Fig. 139.



ferable for the purposes of assisting the navigation. But in engineering there may be many cases in which a captive balloon and pulley will be of the greatest use for lifting weights, such as a succession of stones, to a great height. I shall, however, take occasion in a future page to return to the uses of buoyant gas as a mechanical power.

The next case in which it may be requisite suddenly to change the altitude of the craft is when an obstacle suddenly presents itself in the line of flight. When, for instance, a mountain-peak—if not silvered with snow for the special behoof of the air-sailor in the darkness of night—lies in the way of the craft, and is not seen soon enough to be avoided by steering; or when there is danger of fouling another vessel, some instantaneous alteration of the course must be made. If a mountain be the cause of danger, a rapid ascent is necessary. There is no means of securing this but that of a sudden discharge of weight. On such an occasion the kite-plane will also render invaluable service: it will be thrown either into the vertical position, so as to retard the motion of the craft as much as possible, or into such an angle with the vertical as will resolve the motion as much as possible in an upward direction, leaving the least amount of forward velocity. The driving-engine, too, may be reversed, and the vertical propellers may be worked. But more than this is necessary. Sometimes, in cases of capital emergency, ballast must be thrown out, always, of course, from the central hatchway. However, the weight must on no account be altogether abandoned unless it be absolutely necessary. For it must be remembered that, if the burden of the system be reduced, so as to leave the gas with an excess of lifting-power—and this will always be the case on the slightest diminution of the weight, if the craft were exactly balanced before, as we always suppose to be the case—the whole must continue to rise until the envelope becomes completely filled; and, being unable to retain the expanding gas, continues to discharge it until the lifting power is lost. But since, on a sudden outthrow of ballast, the craft will rush upwards, with a velocity proportional to the weight rejected, if this be considerable, the momentum of the body will carry it up beyond the limit at which the buoyancy recovers its balance by

escape of gas. In such case, the vessel will continue to rise till the momentum is destroyed by the resistance of the air, and then, too much gas having escaped, it will fall quite down to the surface of the earth, unless a further quantity of ballast be discharged. When, then, it is necessary to let a weight fall from the boat for the purpose of a sudden rise, it must always be tied to a strong line, which must be allowed to run out as the weight descends and the craft rises. For this purpose sand-bags of various sizes, all tied to long reeled cords of appropriate strength, must be arranged round the gangway, so that, on the word being given, any number of them may be started by simply touching a spring detent. Each of the ropes must terminate in a length of vulcanised caoutchouc cord, so that, when it is all run out, the velocity of the falling weight may not snap it by the sudden jerk. Each of them, too, must run through a ring, suspended to the boat by an elastic cord, and furnished with a spring catch, which, on being released, shall grasp the cord, and arrest the motion of the weight. By this means the ascent of the craft may be stopped at any required height; for, as soon as the weight is again thrown upon the craft, the upward traction will be neutralised as before. When the craft has risen above the danger, the weight may be hauled up again; or, if it should be requisite, may be cut away. If the latter course should prove necessary, it will be done deliberately, and not, as without the running lines would have been inevitable, on a sudden impulse. If the ballast is hauled up to the vessel again, the balance of buoyancy will, of course, be the same as before, provided that, during the ascent, no gas has escaped from the vessel; if this has occurred, an equivalent of the ballast must be thrown away altogether. However, if the weight be drawn up again by simply winding up the cord, the whole craft may descend to about the same height as that at which it was moving, before the cord began to run out. This, perhaps, may be required, or may not be undesirable, for the obstacle may have been passed in the interim, or the alarm may have been a false one. Generally, if the weight reaches land—unless by ill luck the ballast-line should become entangled and caught by some fixed object below,—it will rest upon the surface of the mountain-top, for instance, and, as the craft moves on, will just

trail upon it, like the guide-rope which is sometimes used by ballooners. In this case the whole system will have been actually lifted to a height exactly equal to that of the summit of the obstacle above the point at which the weight first touched it. And now, when the ballast-line is wound up again, the craft will not descend so low as it was before, but to a point higher than its former position by just this amount. If, however, the weight does not reach the ground at all, the craft will descend as the ballast is pulled up, till the two bodies meet again, at the same, or nearly the same height above the level of the sea, as was that at which they separated.[1] But there will always be this advantage gained, that a rapid ascent was obtained, and that the return downwards may be as slow and cautious as may be desired. It may be

[1] When the ballast is loosed and the cord runs out, the former falls and the rest of the system rises. The ballast is drawn downwards by an accelerating force equal to its own weight, and the gas-vessel is urged upwards by a force of exactly the same kind and amount. At the commencement of the motion the ballast moves much more rapidly than the craft, because its mass, and therefore its inertia, is so much less. The amount of motion in the two is the same, but their velocities are inversely proportional to their masses. Besides this, the resistance of the air to the great surface of the craft will diminish its velocity considerably, will perhaps reduce it to a uniform speed, while the downward motion of the smaller body, which meets with little or no resistance from the air, is continually accelerating. The consequences of these actions will be, that the craft will ascend to a height less by the amount due to the resistance which it meets from the air, than that which bears to the height through which the weight has fallen the proportion of the mass of the weight to the mass of the craft. When the cord is wound up again the same conditions will obtain, the forces now acting in the opposite directions. The weight will ascend faster than the craft descends by the same ratio as that by which it fell faster, but there may be this difference, that the weight being hauled up very much more slowly than the cord ran out, the resistance of the air to the craft in its descent may not be an important quantity, so that the space through which the craft is pulled down may bear to that through which the ballast is raised a proportion not differing sensibly from the inverse ratio of their masses. The result of this will be that the craft will return at last to a position somewhat lower than that from which it started. If it were not for the resistance of the air, the centre of gravity of the system would be at exactly the same height after the recovery of the ballast as it was before it was let go.

necessary, however, to continue the course at the new height, as for instance, if it be required to skim the surface of a country, and the rise has been made not to skip over a ridge, but to gain the level of a table-land. In this case, if the weight be simply drawn up, the craft will be brought down too low; the descent therefore of the former must be opposed by a proper use of its propelling power, either by direct downward waftage, or by the restoring action of the kite-plane. The virtual effect of this will be, that the propelling power is substituting the slow deliberate exertion of winding up the weight for the sudden putting forth of a great force, which it may have been quite unable to accomplish on the instant.

There is a third case of the necessity for sudden alteration of altitude, namely, that which may require a rapid descent of the craft. This, however, can occur but very rarely, since all the obstacles which the aerial navigator will have to avoid arise from below him, and are to be escaped by rushing upwards. The only instance in which this will not be the case, will be when two vessels meet suddenly, and are in danger of collision. The first resort in such emergency will of course be to lateral steering by the rudder, and to the kite-plane. One or other of the vessels, according to the general regulations of the aerial navies, will strike upwards, if necessary, by the mode just described. And this will ensure the safety of both; the one which retains its altitude will only have to avoid the falling ballast-line of the other by steering in a horizontal plane.[1] Almost the only case in which a precipitous descent can be necessary is when by accident a loss of weight has occurred, and the craft has in consequence ascended, or is ascending into a higher region of the atmosphere. But this mishap always carries with it its own remedy; the craft can only endeavour to ascend until the envelope is full, when it arrives at this condition the safety-valve yielding to the pressure of the gas continues to discharge the superfluity of the agent of buoyancy. The propelling

[1] One of the great advantages which the air-craft has over the sea-vessel is that since it is free to move in three directions, while the latter has only the command of two, the danger of fouling is immensely less in the air, by reason of the escape which is offered in every direction.

power of the craft will, of course, be made vigorously to resist the upward traction of the gas, and so will help to relieve the envelope of the strain upon its texture. But in such case it may be necessary, to prevent the envelope from bursting, to discharge more gas than can escape from the tension valve. Again, it may happen that the propelling mechanism may become deranged by the fracture of some essential part of its apparatus, when the craft is at a great height in the air, the envelope being only partially full, and the balance of buoyancy perfect. In this case there will be no other means of descending to the earth, for the necessary repairs, but that of discharging gas.

For such purpose, then, some contrivance must be provided. The same appliance will, of course, also meet all the cases in which, for the maintenance of the balance of buoyancy, it may be necessary to expel a certain quantity of gas from the envelope. I have before said that I do not consider a top valve admissible in a vessel designed for aerial navigation, such an instrument being a source of ever-present danger, not only to the equilibrium of the craft, but to the lives of all its occupants. There can be no doubt that the deaths of MM. Pilatre de Rozier and Romain,[1] in France, and that of Mr. Harris,[2] in England, were caused by the sudden emptying of their balloons, through the top valves being accidentally opened; the gas escaping, and the whole machine being precipitated to the earth. The wonder is that such catastrophes have not occurred oftener. The chances of error with the valve line would be even vastly greater in vessels containing many passengers, and having a variety of rigging, than they are in the 'terrific' toys of the taverns. The 'window to be finished in a cubit above' in the air-ark, is not an opening at top, but the safety-valve a cubit in diameter, in the vessel 'above,' in the 'third story,' at the bottom of it, of course.

Instead, therefore, of giving the gas any channel of escape at the upper part of the envelope, where it may under certain circumstances fly off spontaneously, I would provide for its discharge at the bottom of the vessel, where it never can get out, except by the deliberate compulsion of the master of the gas-vessel.

[1] Turgan, 'Les Ballons,' p. 121. [2] Mason, 'Aeron.' p. 262.

For this purpose then the envelope should be provided with a long wide neck of gas-tight membrane, which should descend from the bottom of the envelope, through an opening in the outer shell of the gas-vessel. This tube must be incompressible laterally, but contractile and extensible in length, being constructed in the same manner as the heating tube before described.[1] It must be fitted, where it joins the envelope, with a valve, which can be opened only at the will of the air-sailor, and its lower end must be brought down to the boat, where it must admit of being fitted, when occasion requires, to the inhaling aperture of a bellows, light pump, or blowing fan-barrel, which may be driven either by hand, or by the artificial power of the craft. If there be a steam boiler in the boat, all that would be necessary would be to tie the end of the neck to a wide tube, into which a steam-pipe enters laterally, terminating within it in a small jet nozzle, directed towards the open end of the pipe. As soon as the steam is turned through the jet, the gas would be drawn out of the envelope by the powerful exhausting action of the steam-jet. The same end would of course be attained by the suction of the pumping mechanism. The upward pressure of the air on the free under-surface of the envelope would in each case force the gas down the tube, within which the pressure is taken off. Such an arrangement would effectually relieve the gas-vessel of any quantity of gas that it might be necessary to discharge. And thus in case of emergency the air-craft, otherwise helpless, would be enabled to descend in safety.

If, as may be the case, perhaps, the craft be provided with an engine to be worked by hydrogen gas,[2] the descent of the vessel may be much aided, if there be any vertical propellers, or if the regular wafts are in order and can be adjusted to an upward movement, by consuming the discharged gas or a portion of it in the engine.

The possibility of using ammonia as a partial agent of buoyancy has already been adverted to; [3] if this device were adopted, the lifting power of the float could be rapidly diminished by

[1] See p. 403.

[2] See Chapter XIV.

[3] See p. 276.

causing the absorption of the gas by one of the substances which can effect this process.

Finally, if the expansion of hot air be resorted to as a permanent coadjutor of the hydrogen in the business of floatage, the descent will be at once induced by withdrawing the source of heat from the air-vessel. The result, too, may be greatly accelerated by pumping the hot air out of the vessel through a tube, which must ascend within it nearly to its top. This may be effected by the same method as was just now suggested for the withdrawal of the hydrogen from the gas-vessel. The place of the rarefied atmosphere being supplied by cold air from without would quickly reduce the lifting power of the float. By proper management the lower part of the gas-vessel, below and without the hydrogen envelope, may be used as a hot air float without the slightest danger.[1] If it fills this function permanently, it will only be necessary to increase the heat when it is necessary to augment the floating power. The gas-envelope, in this case, will of course be protected from the action of the hot air by an appropriate membrane, of texture not liable to injury from this cause.

[1] See p. 403.

CHAPTER XIII.

CONDITION 11.—THE CRAFT MUST HAVE MEANS OF TAKING PURCHASE OF THE AIR FOR PROPULSION AND DIRECTION.

OUR vessels are now complete in their construction and in their fittings, with the exception of their means of locomotion. We have yet to put in their engines; they will then be ready to go to air. In a chapter in the former part of my book, devoted to the subject of the propellers which have been applied to balloons and eggoons, the different forms of which these organs admit were discussed. We have now to consider what instruments for reacting upon the air are suited for employment in such air-craft as those which have been here devised. These limbs as it were of our organism are twofold in nature and in mode of operation, and are to be treated separately as wings and rudder. The former are the most important, and offer a very wide field of variety; the second is a far simpler matter, involving but a single principle, which scarcely admits of more than one form of application. The agents of propulsion, without which the instrument of direction is useless, have the first claim upon our notice.

In a former chapter, I have discussed the principles which must regulate the position at which the propellers must be articulated to the system, the points at which the force must be applied from the craft to the air. In the present chapter, I have only to treat of the construction of the propeller as a separate member of the organism.

Two reasons have been urged by wise folk against the possibility of propelling gas-vessels through the air. The first of these is, that the resistance of the air is too great for us to

hope to overcome it by any exertion of force, applied to wings or to other propellers. The second is, that no 'point d'appui' is to be obtained in the atmosphere for the purchase of our instrument of motion; that is to say, that there is not enough resistance offered by the air to bodies moving through it. These two objections mutually refute each other, and every bird and insect that flies answers them both, severally and together. The resistance of the air to the front of our vessel is, of course, the impediment to its forward motion, and, so far, may seem to contend against us. But this same resistance is the very force upon which we must rely for the effectual working of our propelling power. We know that we can evade, to a certain extent, its first unfavourable action, by properly shaping our vessels: we know too that, if we take it as we find it, when meeting large plane surfaces, it is very great. We know, to wit, that with plane surfaces moving parallel to themselves, the resistance they will meet varies directly as their area, and as the square of their velocity. By taking to ourselves wings, then, of sufficient size, and striking them with sufficient velocity in a proper direction, we can get any amount of resistance. That is to say, if we can provide any given power, we may make the whole, or any required portion of it, available for useful work, by causing it to drive propellers of sufficient size, with such velocity as the force can most conveniently produce. I have already shown that we have yet to learn how far we can diminish the opposing resistance to the vessel. I have now to set down what hints occur to me as to the best means of exalting the favouring resistance to the wafts. It is obviously to the difference between these two dynamical conditions that the motion we shall obtain will be due. It would of course be very convenient if we could work our propellers in mercury, while our gas-vessel was moving through a vacuum. This, however, not being possible, we must do the best we can with the air, the resistance of which is the flyer's best friend, on which he must rely for his swiftness.

It is scarcely worth considering whether a gain may not be effected by making the suspending lines, by which the boat is slung to the gas-vessel, of enormous length, so that, while the latter is moving through a highly rarefied fluid, the former might

be working its propellers in the denser atmosphere below; so getting more resistance where it is required, and less where it is objectionable. But since the conceit occurs to me, I mention it for the benefit of those of my readers who are amusable.

There would be this small gain if the burden be counterpoised by a float linked to it at a great distance above: if the density of the air at the height at which the gas-vessel floats be $\frac{1}{n}$ of that at which it would naturally be slung, the actual resistance with which it will meet will be $\frac{1}{n^{\frac{1}{3}}}$ of that which it would encounter below.[1] Thus, if the suspending lines were $3\frac{1}{2}$ miles

[1] The resistance of the air to bodies moving through it is proportional to its density, which diminishes in geometrical progression for heights above the earth that increase in arithmetical progression. The density of the gaseous contents of the envelope diminishes, and consequently their bulk increases, according to exactly the same law. Therefore a burden that is counterpoised by a given number of cubic feet of hydrogen at the surface of the earth, will require for its sustainment n times that number of cubic feet of the gas at a height where the resistance of the air is one nth of what it is at the surface. But the contents of similar solids are proportional to the cubes of their homologous radii, while their sectional areas, on which will depend the amount of the resistance which they will meet from the air, are proportional to the squares of the same quantities. If, then, the resistance of the air to the appropriate gas-vessel at any given velocity at the leve of the sea be represented by p pounds per square foot of mid-vessel section, and if the area of that section be f square feet, $p\,f$ will represent the whole resistance. Again, the resistance per square foot of mid-section at the new altitude will be by hypothesis $\frac{p}{n}$; and the number of square feet in the mid-section of the large vessel will be $n^{\frac{2}{3}} f$. For, let r be the radius in feet of the great circle of the first gas-vessel, of which the area is f, and let r' be the homologous radius of the second gas-vessel, and v, v' the volumes of the two vessels respectively. Then $f=\pi r^2$, $\therefore r=\left(\frac{f}{\pi}\right)^{\frac{1}{2}}$. Let now the forms of vessels be such that their volumes $=a \times$ cube of radius of great circle. Then $v=a\, r^3=a\left(\frac{f}{\pi}\right)^{\frac{3}{2}}$; and $\therefore v'=n\, v=a\, r'^3=n\, a\left(\frac{f}{\pi}\right)^{\frac{3}{2}}$ $\therefore r^1=n^{\frac{1}{3}}\left(\frac{f}{\pi}\right)^{\frac{1}{2}}$

$\therefore$ the area of the great circle of which r' is radius $=\pi\, r'^2=\pi\, n^{\frac{2}{3}}\frac{f}{\pi}=n^{\frac{2}{3}} f$. The whole resistance, then, of the air to the larger gas-vessel at the greater

long, the gas-vessel would move in an atmosphere of one-half the density of that in which the boat is plying its propellers. The resistance, then, of the air at this height being half of what it would be below, the actual resistance to the progress of the vessel would be $\frac{1}{2^{\frac{1}{3}}} = \cdot 7937$, eight-tenths nearly of what it would meet if it were slung immediately above the boat. Thus much, then, might the propelling force, and therefore the weight of the burden, be diminished—by as much, namely, as is equivalent to two-tenths of the weight of the propelling mechanism. Whether or not this advantage would be countervailed by the additional weight of $3\frac{1}{2}$ miles of rope for each of the sling-lines of the craft, I must leave to the imagination of the reader to determine.

The notion of taking purchase for propulsion on land or sea, which is akin to this, and on which I have already touched,[1] is at first sight more promising. If the surface of the land were level, and that of the sea smooth, and if the air were always calm, there can be no doubt that an exceeding celerity might be obtained by this device. But unfortunately none of these conditions prevail, so, though the plan might be usefully adopted occasionally, it never could become a systematic mode of locomotion.

What we have to study, then, is the means of taking hold upon the air to best advantage by our instruments of waftage—of making the most of its resistance. What, then, is the best method of propulsion?

This is a question which has not yet been solved with respect to water, notwithstanding that the human race has been practising and endeavouring thereupon for some thousands of years in this present æon, and what is more significant, for a score or two of years in this current century. It is not likely, then, that I am going to present a perfect solution of the problem in its aerial application. I wish merely to note down a few hints for experiments—for experiments not 'solitary' but 'in consort,' are what

height, at the given velocity, will be $\frac{p}{n} \times n^{\frac{2}{3}} f = \frac{p.f}{n^{\frac{1}{3}}} = \frac{1}{n^{\frac{1}{3}}}$ of the resistance to the smaller vessel at the lower altitude.

[1] See p. 348.

are required for the improvement of our practice in this as in many other arts.

Now in the propulsion of a floating body by purchase upon the fluid or liquid in or on which it floats, the virtual result is the continual exchange of place between the solid immersed body and the mass of liquid of the same bulk immediately in front of it; and the object sought is to effect this change as rapidly as possible. It is not, in fact, actually the same water that was just before in front of the bows of the steamer, that now lies behind its stern. All sorts of currents and eddies have been set up in the agitated liquid, and from some part or other of the troubled mass some water which, directly or indirectly, has been replaced in turn by the water from the bows, has found its way to the spot just quitted by the ship. But there can be no doubt that if, at every successive instant, the water from before the vessel could be transferred directly to the position behind its stern, the propulsion of the vessel would be perfect. Propulsion thus considered resolves itself into a process of continuous pumping. The best pumping apparatus must therefore be the best propeller. Accordingly, from time to time various methods of propelling boats on the water have been proposed, which have been founded directly upon a recognition of this principle.[1] These, however, have not come into general use. That the ordinary modes of propulsion admit of being viewed in the same light is not at once quite obvious. But the result is the same in every case of locomotion through water or air, the transference of the liquid or fluid from stem to stern being effected indirectly, if not directly, by the instruments of waftage. The paddle-wheels of an ordinary steamer are, in fact, nothing but contrivances for pumping the water from the vessel's bow to its stern, and I must say the common paddle-wheel does seem to me as clumsy and barbarous an appliance as could well be devised for this purpose.[2] And that the screw propeller as at present applied,

[1] See 'Mech. Mag.' vol. xxxii. pp. 518, 527; vol. liii. p. 159; vol. liv. p. 198.

[2] The conditions of aquatic surface-propulsion are, of course, very different from those of locomotion through the air. Submarine navigation would be the true analogue of our aerial art. But this branch of human

in the best of its numerous forms, is a most imperfect instrument, is evident to anyone who will compare the relative sizes of a

skill is yet to be developed. The diving-bell is to the future deep-sea boat what the balloon is to the air-craft. The few submarine boats which have yet been used (for such have been shown in successful action by more persons than one) represent the experimental eggoons which have crawled along in the air on one or two occasions. There can be no doubt that rapid motion is much more easy to be attained within the waters than upon their surface. There is not in all nature an animal that moves with rapidity at the top of the water, with a part of his body immersed. The water-beetles that dart about on the surfaces of ponds, rather run upon them than swim partially immersed in them. The so-called swimming of the ducks and swans and other surface water-fowl is scarcely locomotion at all, it is a mere aquatic creeping. But how different are the underwater movements of the diving birds, the truly prototypical water forms of the feathered circle! The velocity with which they dash through the liquid is sufficiently shown by the ease with which they catch their finny prey within it. The gulls and terns, the aerial forms in the watery sub-circle, and the sea-eagles and ospreys, aquatic members of the proper air-group, obtain the speed requisite for their underwater chase by falling headlong from a height. The auks and grebes simply put their heads beneath the surface, strike out with their feet, and with outstretched neck cleave and thread their way through the liquid like the swifter of the fishes. Those who have seen the little grebe or 'dab-chick' dashing through the weeds in some swift clear river like any trout, and have wondered how a thing so slow in its movements on the surface could find new means of locomotion in the denser liquid which it had not when its body was partly in the rarer air, though its propelling feet are in the same favourable conditions in either case, will be ready to believe that, for some reason or other, rapid movement is more easily accomplished within the waters than upon them. Such, at any rate, is the fact. One reason why the birds can proceed with greater velocity under water is that they stretch out their necks, and so present a form more favourable for speed than they do when floating at top. Perhaps, too, they sometimes use their wings for sub-aquatic propulsion.

But there are other agencies which oppose the attainment of a high velocity at the surface, but do not interfere with the desired result when the body is entirely immersed. In the first place, the irregularities of the surface are continually altering the amount of resistance offered to the propellers, as well as that which the advancing body meets with. In the next place, curvature of the fore-part of the ship's bottom, meeting the pressure of the resisting water, must resolve it partially in an upward direction, and so, even if the propelling force is applied in the most advantageous manner, that is, entirely in a direction parallel to the length of the vessel, a portion

salmon's tail and body with those of a modern steamship and its screw.

of it must be expended in lifting the bows of the vessel slightly out of the water. Again, the forward pressure of the vessel, in displacing the water, tends to raise the liquid about its bows, and to leave a depression behind its stern, thus increasing both the actual resistance from before, and by withdrawing the hydrostatic pressure from the after surface, the negative resistance behind.

None of these opposing influences prevail beneath the surface. There there are no storms, no waves, no adverse winds, no tendencies to misdirection of the available propelling power. The speed that we may attain in submarine boats is hinted to us by the velocity of many fishes, of seals and of whales. But to compete with them we must imitate their forms, and improve upon them. Long arrow-shaped figures, similar to those that will be required for air-craft, must be made use of. The best form will be learned by experiments conducted, like those of Colonel Beaufoy, with bodies immersed beneath the surface of water. No doubt his results will be of service to the future art, though they may be useless to the surface-sailors of the present day.

Contrivances will of course be necessary in the submarine boat for maintaining the horizontal balance, because the pitching and rolling of the vessel will not be limited by the mass of the displaced liquid, as it is with bodies floating at the surface. The fishes manage this with their fins. The deep-sea boats will be furnished with a pendulum-level and shifting ballast, or vertical propeller such as has been described for the air-craft (see p. 362).

Submarine boats intended for slow motion for under-water engineering, may be open to the water below like a diving-bell, and may derive their supply of air from the atmosphere above by a pipe running up to the surface, and having its mouth kept floating at a sufficient height above the water to prevent the liquid from getting access to it. Air would be drawn down the pipe by a pump worked within the boat. The foul air would be discharged from time to time by an appropriate pipe at the top of the vessel. But a totally different arrangement will be necessary in the rapid deep-sea craft. The whole vessel must be closed and air-tight, and must be dependent on resources within itself for its supply of air. The whole must be strong enough to resist the pressure of the water from without, which will not be balanced by the pressure from within, for the inner atmosphere must be maintained at the degree of rarity which may be most agreeable to the voyagers. The quantity and purity of the air within the boat may be regulated to the greatest nicety by supplying pure oxygen from sources carried in the vessel, the carbonic acid generated by respiration, and perhaps by combustion, being absorbed by alkaline leys. The nitrogen of the air b g

An interesting experiment might be, and indeed ought to be tried, first for the purpose of ascertaining how far the real powers

unaffected, or nearly so, both in amount and in quantity, by the processes of combustion and respiration,—serving only to dilute the oxygen that operates therein—is a constant quantity which will remain unaltered throughout the voyage. This is a natural fact which favours submarine navigation. A second is that the carbonic acid produced by the combination of oxygen with carbon, and which is exhaled from the lungs as oxygen is inhaled, occupies exactly the same bulk, equivalent for equivalent, as does the gas from which it is produced. Thus by its evolution no gaseous expansion, and therefore no increase of pressure beyond that which is effected by the heat generated in its formation, will result in the air enclosed within the boat. By causing the whole atmosphere of the boat to circulate slowly, and in its passage to be drawn through milk of lime, the whole carbonic acid will be removed; and by a regulated flow of oxygen from appropriate reservoirs, the bulk and quality of the air will be kept up continuously and together. The oxygen may either be prepared beforehand and condensed in strong metallic cylinders, from which it is allowed to escape gradually by small apertures, through which its flow is regulated according to the requirements of the voyagers, or may be generated within the boat from chlorate of potass. It appears that a man consumes 46,037 cubic inches, = 26·6 cubic feet of oxygen daily. Now 100 cubic inches of oxygen weigh 34·2 grains, so that a man's daily supply weighs $\frac{34\cdot2 \times 46{,}037}{100} =$ 15744·7 grains. Now chlorate of potass = K Cl O6, contains 39·2 parts by weight of potassium, 35·5 of chlorine, and $6 \times 8 = 48$ of oxygen. Since the whole of the oxygen is evolved from this salt when heated, 122·7 parts of it will yield 48 of oxygen. Therefore a man's daily ration of oxygen-material will be $\frac{122\cdot7 \times 15744\cdot7}{48} = 40247\cdot4$ grains, = 5¾ pounds of chlorate of potass.

The interior of the vessel will be lighted by the voltaic arc, to avoid the consumption of oxygen which would be entailed by any other source of illumination. One or two of these lights at head and stern placed immediately behind strong glass bull's-eyes, and furnished with reflectors, would shed through the waters at night, and when the course lies deep, light sufficient to warn other vessels of the danger of fouling, and to make rocks, bottom, and other solid obstacles visible to the watchmen within. The watchman will of course be in a dark chamber immediately beside the light, and furnished with a thick glass window, so that the only light that could reach his eye would be that reflected from objects without the boat. But when we have so far done our duty as to have conquered air and sea as well as earth, we shall probably be permitted to profit by the other means

of the engines of a steamship are actually made available for its propulsion by paddles or by screw; secondly, for showing within what limits, by improving the propeller, the speed might be increased. When the engines of a steamer are built, let them be fixed on the harbour shore; and let the ship that is to receive them be loaded with a weight equal to the engines and to its full complement of cargo and crew, and placed at a convenient distance from the shore. Let a rope be attached to the bows of the ship by one end, the other end being on shore. Let now the engines be made to work as a stationary hauling power, to drag the vessel through the water to a sufficient distance to enable it to acquire a uniform velocity, and its rate of motion to be observed. When, after a sufficient number of experiments, the actual value of the engine-power in speed of the vessel had been ascertained, the engines being put into the vessel and the propellers fitted on, comparison would be made of the results obtained from them with the real capabilities of the power. There can be no doubt that it would be shown that the best propeller that is in use did no justice at all to the engines of the steamships.

The objects aimed at in the construction of all propellers should be, of course, to enable them to take as firm a hold of the water as if they took purchase against solid earth. The hold of

of vision which are sleeping within us, of which the only uses at present seem to be for charlatans to cheat the credulous with, for *savants* to sneer at, and for philosophers to ponder on.

The submarine boat will be steered by a double rudder, combining the forms of the whale's and of the fish's tails, formed of two flat plates intersecting each other at right angles. It and the propellers will of course be worked by spindles passing through water-tight stuffing-boxes in the boat's shell. There will of course be no necessity for the boat diving to great depths; if it move just far enough below the surface to avoid the waves, it will obtain the full benefit of its powers. During the voyage occasional ventilation with fresh atmospheric air will be easily accomplished, and for comfort's sake will be resorted to.

The true principles of propulsion will no doubt be applied to the conduct of these vessels, and by the combination of appropriate forms of body and mechanism results must be obtained before which the boldest efforts of our present navigation companies must sink into insignificance.

the propeller on the water depends on the resistance of the water to the motion of the solid body through it. Now this resistance depends jointly upon the square of the velocity of the motion of the propeller and upon its area. The resistance may be increased theoretically by increasing either. Now it is, no doubt, much more convenient to make the propellers revolve with great speed than to make them large. Accordingly, engineers seem to trust for resistance rather to the speed with which their paddles or screws can be made to spin, than to the areas of their striking surfaces. But, in fact, they fail in attaining by this means the resistance and speed to which they are entitled. Bodies moving at high velocities in small circles are under totally different conditions from those of bodies travelling in right lines. Thus the blades of paddles or of screws, revolving in circles of great curvature, do not meet with the same increase of resistance on acceleration of their speed which they would encounter, if they were moving parallel to themselves. There can be no doubt that the actual resistance which they meet with in the required direction is less than it would be if each point in their surface moved in a right line. If, however, the increased resistance be sought by increasing the area of the surfaces, there would be no reason why the full amount of purchase should not be obtained upon the water. In nature we nowhere see great velocity of locomotion obtained by small propellers, moving with vast speed in small arcs. All the rapid fishes have large tail-blades, which they sweep to and fro through large arcs, when they shoot themselves forwards with high velocity. But my business is with the air, not with the water. Here again, however, all the swift flying birds and insects have large wings, or at least long ones, so that the velocity of the propelling surfaces is obtained, not by making them move with rapid alternations through small arcs, but by making them sweep through arcs of larger circles. The wings of the swift do not vibrate faster than those of a sparrow; but the length of the primary feathers being so much greater in the former bird, their extremities move through larger arcs, and therefore with greater velocity.

Howbeit, let the water boats, long or short, upon or beneath the surface, propel themselves as may seem best to ship-builders

and water-sailors. The hope which I have to express is that those who hereafter may be moved to the navigation of the air, will, when they furnish their vessels with wing-wafts or screw-vanes, make them of size sufficient to do full justice to their engines; and that they will obtain for their propellers the required velocity, not by multiplying their strokes or revolutions, but by increasing the length of their radii. In offering the suggestions and further remarks which I wish to make as to the instruments of propulsion, I shall consider these under three heads, as in the corresponding chapter in my former part, viz., as firstly, alternate wafts; secondly, rotary vanes; thirdly, continuous jets.

The first, or to and fro acting wing, is undoubtedly the simplest form of mechanical instrument of progression which can be applied to the air. I think it very likely that it may be proved hereafter to be the most serviceable in practice. It is almost the only one of which we have any example in nature, certainly the only one which has been worked out to any extent in the great scheme of animation. In the simplest arrangement for human aerial transit, that of the single flyer suspended boatless from his float, there can, I think, be no question as to the kind of propeller best fitted for service. I think that a pair of wings fitted to the framework already described[1] about the shoulders, and worked by the extension of the legs, with the occasional assistance of the arms, would be more effective and more convenient than any other instrument. The amount of power which the human legs are capable of supplying has been already discussed,[2] and does not belong to this part of my subject. The mode, however, in which the power is given out is of some importance. Almost the whole available force of the legs resides in the extensor muscles; those which bend the legs are but weak, having but little natural duty to perform beyond that of lifting and moving the limbs themselves. The chief part, then, of the work of flying must be done by the extensor muscles. Now this labour is twofold—firstly, the wings have to be thrown back for the stroke; secondly, they have to be recovered. During the return stroke the wings must, of course, be feathered or folded,

[1] See pp. 301–3. [2] See pp. 24, 351.

so as to reduce the resistance which the air will offer to them in this direction to a minimum. This movement will therefore require a far less exertion of force than will the stroke proper. The two actions may be effected in three ways. Either the work of propulsion may be done by the two legs, each for one wing, and each wing may be recovered by one arm—or one leg may work both wings at once in one direction, the other leg bringing them both back. The two legs might thus, by alternately taking the severer labour, relieve each other; thirdly—and this would probably be the best mode of action—the wings might be brought down by the legs acting either both together or alternately on both wings, or each constantly on its own appendage, the recovery being effected by springs. In this case the whole work is done by the legs, for during the down-stroke the additional labour of stretching the springs is necessary—the arms are left at liberty altogether, and no muscular force has to be exerted during the return-stroke.

The rapidity with which the strokes are made will be a physiological question for each flyer. For though the amount of power which two men are capable of furnishing may be the same, the rate at which they can move their limbs may differ widely. The resistance which the wing will meet from the air will be determined jointly by its velocity of motion, and by its superficial extent. Now it is quite certain that for most people it will be far more easy to give out the available power of their legs in long slow strokes, than in rapid kicks in quick succession. And this is especially the case where, as in our wings, the mass of matter to be set in motion is considerable. With a light oar, a short quick stroke is as easy as a long one, but a heavy oar requires time for the overcoming of its inertia at the beginning, and for the exhaustion of its momentum at the end of the stroke. The velocity of the wing will not therefore be obtained by swift to and fro vibrations in arcs of small circles, but by vigorous long sweeps. The length of the path of the wing and its velocity will be determined jointly by the length of its radius arm, and by the distance from its hinge of the point at which the link connecting it with the foot is attached. The wing-arm will be articulated by a strong joint to the framework in which the

body is slung. The position of this joint will be near the shoulders, and its construction such as only to admit of motion in a plane parallel to the length of the body. A tendon cord attached to each wing-arm at a certain distance from the joint, and having a stirrup at its free end to receive the foot, will communicate the motion from the leg to the propeller. By shifting the point at which the tendon is united to the radius, the flyer will be able to alter at will the extent of the arc through which the wing is moved at each stroke. The wings will of course be made of bamboos, or of malacca canes, strengthened with braces and ties, and having stretched between their ribs light webs of silk or linen. The weight of each wing must be counterpoised by a loaded arm extended on the opposite side of its hinge-joint, so that whatever may be the position of the wing or direction of its motion, its weight may never be thrown on the spring or muscles which have to recover it for the stroke. It would be a further waste of paper to describe possible forms of wings:—a different shape with a different adjustment for feathering might be suggested for every hour in the year. Every flyer may have his own device for this. But the essential points to be attended to are the size of the wing, the length of its radius, and the extent of its arc of motion. The quantity by which, ultimately, all of these must be determined, is the area of the mid-section of the gas-vessel by which the flyer floats. The resistance of the air to the forward flight, the amount of work to be done, will be dependent upon this measurement, the general form of the gas-vessel being supposed constant. The wing must be so formed as to enable this exertion to be made with the least labour on the part of the flyer. I shall reserve for the application of the wing-waft to boat propulsion what more I have to add about its structure and proportions.

The form of air-craft, which naturally follows the simple flyer, is the vessel propelled by human labour. I have already described one possible arrangement of a rower's air-craft, in which there was no distinction of parts,—no separation of man and gas-vessel.[1] What I have here to say refers only to boats slung from floats, according to the methods before laid down.

[1] See p. 294.

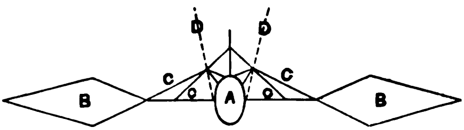
The principles in the construction and management of the wings concerned will be exactly the same, whether the work be done by a single individual, or, co-operatively, by two or more. If there be only one rower, he will, of course, as in a river sculler's boat, pull one propeller with each hand. If there be two, each will work one wing. If there be more than two rowers, their number will of course be even, and their wafts, each working one, will be distributed symmetrically on each side of the boat. I shall describe what I conceive to be the best arrangement for the accommodation of a pair of rowers. The application of the same instruments to the service of other combinations is simple, and need not be specified.

That the two wafts may have a similar action upon the two sides of the vessel, without any tendency to turn it round horizontally, as well as for the symmetrical appearance of the craft, it will be desirable that the two wings should act upon the system at points opposite to each other in the same cross-section of the boat. But since it will always be desirable to make this cross-section as small as possible, so that its form may be the best suited for cleaving the air, the rowers will not sit side by side, unless other circumstances should require the boat to be wide enough to admit them. They will be placed one behind the other, as in an ordinary river rowing-boat. This mode of arrangement will have the additional advantage of distributing the burden over a greater part of the length of the gas-vessel. Further, that the rower may never have to support or to lift the weight of the wing, the in-board lever arm of each wing must be furnished with a weight, which counterpoises the whole load of the wing. This weight must be movable on the arm, and must be furnished with a binding-screw, for fixing it in any required position, nearer to, or farther from the fulcrum, so that, when the wings are wet, the additional weight thrown upon them may be duly balanced. This counterpoise adds of course greatly to the burden of the gas-vessel, but it is nevertheless absolutely necessary, if the wing is ever to be moved in any other direction but the horizontal, as for the purpose of mounting directly upwards, or descending vertically.[1] If however the motion of

[1] The Turks balance the oars of their boats as in the caique (1851) on the Serpentine in Hyde Park; and excellent, both in style and vigour, was

the wafts is to be confined altogether or nearly to a direct pull fore and aft, the weight of the wings may be equally well supported, without farther loading the craft, by a stay or sling attached to the upper part of the side of the boat, or to a sprit specially strutted and stayed for the purpose on the top of the boat, in the same vertical line with the rowlock of the wing,—as

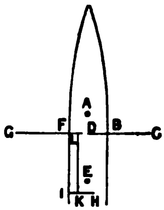
Fig. 140.



in fig. 140. Here A is the boat in section, BB the wings, CC the sustaining wing-stays, DD the ropes suspending the boat from the gas-vessel.

The arrangement by which I would propose to effect the movements of the wings at joints lying in the same cross-section of the vessel, while the rowers sit one behind the other, is represented in fig. 141. Here A is the position of the fore or bow rower, B is the hinge or rowlock of his wing, BC the out-board arm of it; BD the inner arm or handle; E is the after or stroke rower; F the rowlock of his wing; FG its out-board limb. The in-board part of this wing-lever is very short, occupying the free space between the end D of the other wing-handle and the side of the boat, just long enough to form a lever arm and joint as described below, and, if necessary, to carry a counterpoise to balance the weight of the wing.[1] The rower at E is to move this wing

Fig. 141.



the pulling of the red-capped gentlemen who brought it over here for exhibition. The advantage of this Turkish counterpoise is pointed out by Mr. Macgregor, in one of his lively letters in the 'Mechanics' Magazine,' vol. lii. p. 351.

[1] Since, however, this arrangement of the wing will not admit, without further complications, of force being effectually applied to it in any other direction than fore and aft, the weight of the wing had better be sustained by out-board slings than by counterpoise.

by means of a handle H, which terminates a lever HI of the same length as the in-board arm of the other wing. At I this lever is jointed to the side of the boat, exactly at the point where the rowlock would be in the ordinary mode of rowing. This joint admits of motion to and fro, just as does the rowlock of the wing, at a point K in I H, such that the length of I K is exactly equal to the length of F L, the short in-board arm of the wing-lever, and is to be articulated by a hinge to one end of a straight rod, K L, the other end of which, L, is jointed to the end of the wing-lever, so that I H is parallel to F L. The link, K L, thus runs parallel to the line joining F I, and F L K I forms a parallelogram, at each of the angles of which is a joint permitting motion in the plane of the parallelogram. Any motion then which is given to the point K, by the hands of the rower at H, will be exactly followed by L, and the wing will move exactly as if it was urged by the force of the rower applied at a point of its in-board arm, prolonged at the same distance from its rowlock as H is from I, or L from B.

The action of rowing an air-boat must be much simpler than the same exercise on water, because the whole movement of the wing-lever in the former case takes place in a horizontal plane, whereas in aquatic rowing each point in the length of the oar must describe an elliptical figure, the blade being dipped down into the water for the stroke, and lifted into the air for the return. It is, of course, beyond comparison a far simpler movement than that of the flight of any animal that has to support its own weight.

The only manœuvre besides the mere to and fro motion which our boat-wing must execute, is that of feathering to elude the resistance of the air in the forward or return stroke. This may be managed either—firstly, by making the wing-blade a single plane surface, rigidly attached to the arm or beam; and by causing the beam to rotate on its long axis through a quadrant at the beginning and end of each stroke. Secondly, by making it of two planes, each hinged to the beam, one above, the other below it, so that the two leaves shall open during the back or effective stroke, and shut up during the recovery. Thirdly, by making the wing of a series of thin plates set parallel to each

other, so that each may feather separately like the ribs of a venetian blind. Fourthly, by making it of thin plates set radially from a common centre, so that they may spread out and shut up like a fan. Fifthly, by making it of web, which may be stretched during the stroke and folded up during the return. This movement might be effected by the working of a set of parallel levers arranged on the principle of the lazy tongs, or by mechanism similar to that of the duck's foot or of an umbrella. Whichever of these plans of feathering be adopted, the function should be made self-acting, so that the wing-arm meeting at the proper points in its course certain catches and levers, should suffer the required adjustment without any special operation on the part of the rower.

Of all these methods I prefer the second as being the simplest. The form of blade which I should recommend for this wing is shown in fig. 142. A B is the rod or beam of tapering bamboo; C B is the part of it which bears the blade; C A the part between the blade and the rowlock; C D, C E, C F, C G, cross-sprits of bamboo, fixed to the beam at C for the purpose of giving support to the wire-cord stays F E, E D, &c., &c., which confer stiffness and strength upon the whole. The arm C B should be slightly curved, with its concavity towards the after part in the horizontal plane, by bracing up the stay E B, so as to make it shorter than C B, O C, O P, sling-stays for supporting the weight of the wing and relieving A C of strain. The blade is to consist of a web-cloth stretched upon a framework of cane-sprits, and bound throughout its length to the main beam which runs along its middle. Each of these sprits must be tough and springy, and is to be bent into the form of a bow, and strung by a cord drawn tight between its free end and the point where it joins the beam. This is to give it stiffness to resist the pressure of the air on its working surface. The concavity of the bows will be towards the after-side of the wing; this will have the additional good effect of assisting the curvature of the beam in giving a spoon-form to the blade, which will favour the hold of the wing upon the air[1] during the stroke (see fig. 143), with the further advan-

[1] The best form of wing as respects concavity is hereafter to be determined by special experiment.

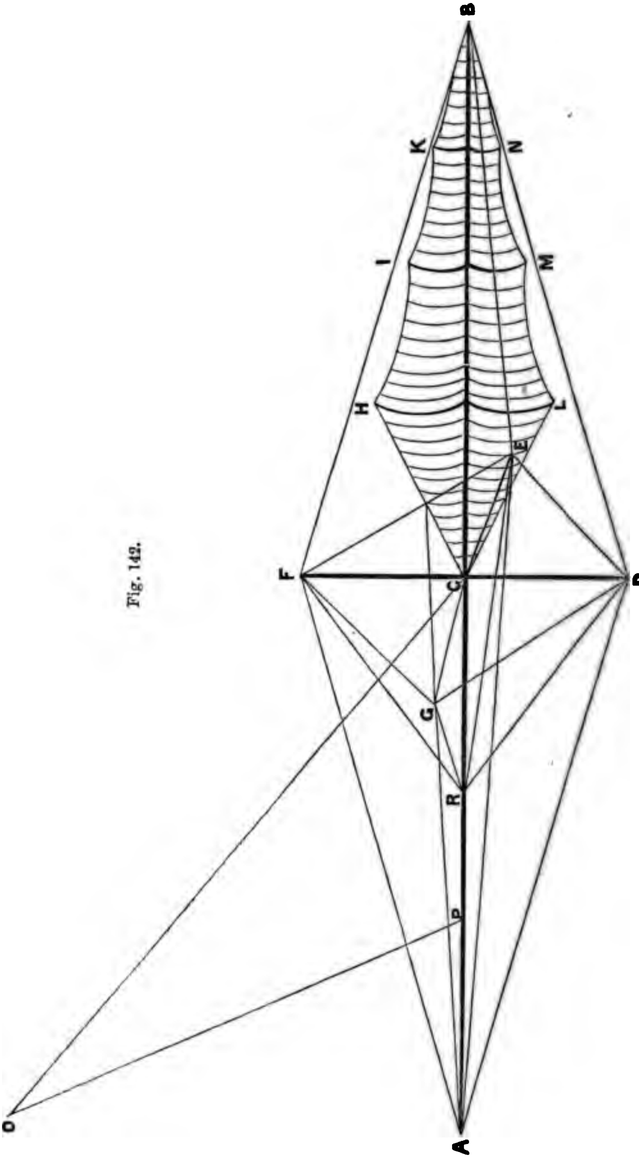


Fig. 142.

tage that the two curved surfaces, when the wing is folded, will form a figure well suited for cleaving the air during the back stroke (see fig. 144). Each of the web-sprits must be hinged upon the beam at the point where it meets it, so as to allow of motion in a plane at right angles to the length of the wing, to enable the blade to shut up and to open freely. Their outer ends, H I K, L M N, must be tied by stays either to sprits projecting a tright angles between them towards their concavities, or to the mainbrace E B. The object of this is to prevent the wing from opening too far, and to arrest it in the position in which it will receive the greatest resistance from the air. Each of the web-sprits must be furnished with a spring, such as a back-stay of vulcanised caoutchouc, which shall be stretched when the wing is folded close by the return stroke, so as, on the commencement of the working stroke, to start the blade open, that it may receive the resistance which will ensure its full expansion. Figs. 143, 144, represent the wing in cross section in the positions in which it will be when open and folded, in the stroke and recovery respectively. A, the beam; A B D, A C E, the bent sprits; A D, A E, the strings of these bows; A F, A G, strong stiff sprits, for giving support to the braces, F D, F E, G H, G I (these sprits may perhaps be dispensed with by tying the braces to the mainstays of the wing); F D, F E are loose when the wing is folded, tense when open; G H, G I are in the reverse condition, being, besides, elastic, so that when the wing is quite shut they exert a slight strain to open it. By stretching a web over the cords G H, G I, from end to end of the blade, a cut-air or knife-edge will be formed, which will further diminish the resistance of the air to the wing during the return stroke.

Fig. 143.

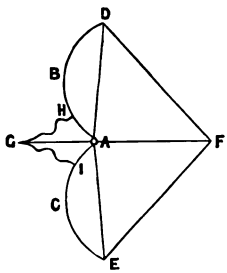
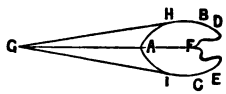


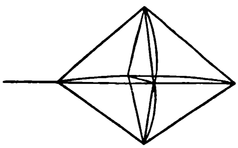
Fig. 144.



The proportions of the wing, as respects its form, may of

course be greatly varied. That represented in fig. 145 is of the kind of shape which I would recommend for smart, swift-flying air-craft. The shortness of the web-sprits will enable the wing to open and shut with rapidity. For vessels of burden, which will not require so high a velocity, but which will meet with a great resistance from the air by reason of their large size, I would suggest a broad wing of some such figure as that sketched in fig. 145. The art, however, of cutting and constructing the wings, which are truly the sails of the air-craft, will be as distinct a branch of practice as is the sail-making of ships. The air-craft will, in fact, sail in the air as truly as does the ship upon the sea, the difference being that the masts and sails of the latter are fixed and receive the wind, those of the former move and make their own wind.

Fig. 145.



The motion of this sort of wing being simply a to and fro motion in a horizontal plane, the axis on which it turns must be vertical. The rowlock may be formed thus:—A circular aperture will be cut in the side of the boat, of sufficient diameter to admit of the oar-beam passing through it, and having free play through the arc necessary for the sweep of its blade. This hole will be framed with a metal ring, bevelled off inside and out. This ring will be fixed to a strong light rib-work of steel tubes, with which the boat must be provided to enable it to resist the strain of the propelling force. The rowlock-ring will support the pivot on which the wing turns; for this purpose it will have a steel cup or step at the middle of its lower semicircle, and a collar formed

Fig. 146.

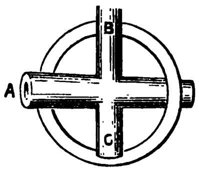
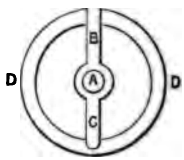


Fig. 147.



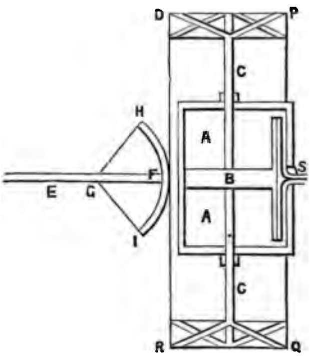
in the middle of its upper half. The pivot of the oar (fig. 147), will be a short piece of metal tube A, through which the beam

will pass, with a steel pin projecting from two opposite sides, at right angles to the bore of the tube. One of these pins, C, will terminate in a hemispherical end, which is to work in the cup on the bottom of the rowlock ring. The other, B, is to be a cylinder, and is to pass through the collar in the top of the ring, as in fig. 147. If the wing be balanced and fitted for occasional use in a vertical direction, the ring which supports the thole-pins, B C, must be made to traverse round within another which is fixed in the boat's side. In this case both of the pins should turn in a collar, being kept in their places by a shoulder, and the shifting ring must be provided with pegs for fixing it in any required position. This, however, will scarcely be possible except with the smaller and lighter wings for manual labour, for the beam at the rowlock will not be strong enough to bear the weight of the wing and the resistance of the air to its blade, if the latter is heavy and the force used very great, as will be the case when artificial power is used for the propulsion of the larger air-craft.

The next variation in the use of a wing for the propulsion of air-craft is when artificial power is applied to the production of motion. I shall briefly describe the mode according to which I would connect the wing with the driving mechanism, when steam or any expanding gas is used as the source of power. The reciprocating action of a wing or oar is one so easily and simply produced by this kind of agent that it seems peculiarly fitted for this purpose. The arrangement of the beam and thole-pins will be the same as for the rower's wing just described, if the apparatus is on a small scale; for the high-class air-craft a somewhat different arrangement of the wing will be necessary. The diagram, fig. 148, represents the form of steam-engine which I would suggest for this method of propulsion. It is a reciprocating engine on the ordinary principle, there being a separate cylinder for each wing, its only unusual characteristic being its extreme simplicity and lightness. A A is the cylinder in section, lying horizontally with its axis in the plane of the wing-beam; B, the piston; C C, the piston-rod, passing completely through the piston, to which it is fixed at the middle of its length, and terminating at each extremity in a cross-head, D P, R Q. The motion of the piston-rod will be kept steady by guide-bars, not

shown in the diagram, running parallel to it in a plane at right angles to that of the cross-heads, or by making the stuffing-boxes, through which it works in the covers of the cylinder, very long. E F, part of the wing-beam; G, the point where it rests on its axle in the rowlock; G F, the in-board arm of the lever; H F I, an arch head, fixed on the end of the wing-arm in a horizontal plane, the radius of its circle being the length of G F, and the length of its arc equal to the length of the piston-stroke; D F I, R F H, cords of wire-rope stretched between the ends of the arch head of the wing-arm and the cross-heads of the piston-rod; P Q, a strong bar joining the opposite ends of the cross-heads; S, the valves or slides for regulating the admission and escape of the steam to and from each end of the cylinder. The piston will act directly upon the wing, which will make one stroke for each stroke of the piston, the rectilinear motion of the latter being converted into angular motion about the rowlock as a centre, by means of the cords D F I, R F H, and the arch head. The use of the bar P Q will be to oppose the strain tending to bend the piston-rod towards the wing, and also to work the valves or slides at S. These must be so arranged as to cut the steam off at such part of the stroke that the momentum of the wing shall be just sufficient, aided by the expansion of the steam or gas, to carry it on to the end of the stroke.

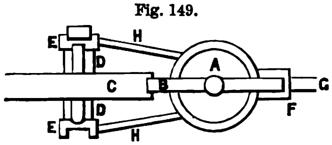
Fig. 148.



If the wing be a small one, and the work which it has to perform not very heavy, so that the beam is able to support the strain to which it will be exposed at the rowlock, without being assisted by stays, this same movement may be applied to working the wing in any other direction, such as in a vertical plane, by a very simple adjustment. This will be effected by so uniting the cylinder to the wing-arm, that they may both be moved together on the same horizontal axis, so that in whatever position they

may be placed, their mutual relations will remain the same. Let A be the working cylinder seen endwise; B one of the cross-heads; C, the wing-arm; D, the thole-pin; E, the rolling row-lock, which turns in the side of the boat; F, the valves; G, the steam-pipe, with a steam-tight joint, admitting of a revolution of the cylinder and all parts connected with it about an axle passing through this point as one of its pivots, the other being formed by the rowlock-ring, E. It will be seen that the whole working part of this mechanism may revolve round the horizontal axis, passing through the centre of the rowlock and of the steam pipe, without in the least affecting the motion of the piston and wing. Thus, even in the middle of a stroke, without interrupting the play of the wing, the whole engine, beam, and waft may be turned round so as to act in another direction, in which it may be fixed at pleasure.

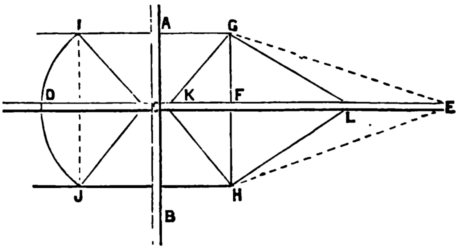
Fig. 149.



It is evident that, with oars or wing-wafts worked in this manner, the whole strain due to the resistance of the air to the blade, and to the power acting on the in-board arm of the lever, will be borne by the wing-shaft, which will thus be subjected to a system of forces striving to break it at the rowlock. In the case of small vessels propelled by manual power, the shaft or beam may easily be made strong enough to resist by its own tenacity the tendency to fracture. This will of course be effected by giving sufficient thickness in the plane of oscillation, to that part of the beam which would be most liable to fracture, and by strengthening it, if necessary, by the addition of steel tubes to its substance. This form of structure will be sufficient for any such wings as are not too ponderous to admit of the direction of their motion being changed by means of the revolving rowlock. For the heavier wafts of larger vessels, which will only be required to play in a horizontal plane, and which, being urged by much greater powers, will have to resist a very severe strain, other appliances must be resorted to for ensuring the strength of the propellers. These movable masts will require stages for their support, as much as do the fixed masts of the larger water-craft.

It is clear however that they cannot be stayed, like the masts of ships, to the sides of the vessel in the plane in which the resistance is demanded, as they are to be free to move in that plane. Neither can the stays be attached to sprits standing in the usual manner on the main beam, at its weakest point; for the rowlock and the sides of the vessel would come in contact with such appendages, and would consequently prevent the motion of the wing. The desired firmness may however be conferred upon the wing-arm by the following arrangement. Let AB (fig. 150) be a

Fig. 150.



part of the side of the vessel with the rowlock at C, CD the in-board arm of the wing-beam, CE part of the out-board shaft, the plane of motion of the wing being that of the paper; FG, FH, sprits standing on the wing-arm at the point F, at right angles to CE, in the plane of motion. F is to be at such a distance from C, that the sprits FG, FH, will always be clear of the vessel's side, even at the end of the stroke in both directions. IJ, the extremities of the arch-head on the in-board arm, in case of such an arrangement of the moving power as that described in fig. 148, or the ends of two sprits similar to FG, FH; GK, GL, GE, stays of wire cord, passing from the extremities of the sprits to suitable points on the wing-beam. GI, HJ, similar strong stays joining the extremities of the out-board sprits to the ends of the arch-head or in-board sprits. GK, HK, must lie at such an angle with the beam that, at the termination of its stroke in either direction, no part of either of them shall touch the side of the vessel. GI, HJ, must pass through slits cut in the side of the vessel, of such length as to leave them free in every position of the wings. It is

obvious that the security of the beam against fracture will depend mainly on the strength of the stays, G I, H J.

The form and structure of the wings being thus provided for, their size remains to be considered. This is a matter at least as important as any other connected with the propulsion of the craft. Now the object of the propeller sails is to obtain from the air the greatest possible resistance that can be produced by the available moving power. And the resistance which they meet with when set in motion must be greater than that which will oppose the progress of the craft in the opposite direction. The resistance to the wafts depends firstly on the extent of their surfaces, secondly on the velocity of their motion. Their velocity will depend firstly on the speed of the engine, or on the number of strokes which it makes in a given time; secondly, on the distance between the centre of the sail and the fulcrum at the rowlock. Given the area of the wing, the same velocity may be given to it, either by a quick stroke of the engine, with a short wing-arm, or by a slow movement with a long radius. The greatest amount of resistance that can be obtained for the wing is that which will balance the force exerted by the moving power. This, of course, is the limit, and when this is attained, the result will be the same as if the wing were a lever working against a post or fixed fulcrum outside the vessel. But however perfectly our propeller may be adapted to the fluid in which it moves, and to the work which it has to perform, its effect will always fall short of this amount. The object arrived at in the construction of the sail must be the reduction of this deficiency, due to the 'slip' of the wing through the air, to a minimum. Now any given amount of resistance may be obtained either by adjusting the area of the wing, the speed of its motion remaining unchanged, or by adjusting the velocity, the size being constant. Now, as I have already pointed out, it is much better to obtain the requisite velocity of the wing by giving it length of arm than by relying upon a very rapid to and fro movement, with a short radius. However, in constructing his propellers, the engineer will be guided by a careful consideration of the weight and strength of the materials of which it is to be composed. It must be remembered that, given the area, and consequently the weight

of the sail, the longer the out-board arm is made, the greater will be the strain due to gravitation on the rowlock, or on the swing-stays, by which it is slung from the vessel, or the greater must be the counterpoise on the in-board arm. Again, he will have to calculate whether a small wing with a long arm will be lighter than a larger area of canvas with a shorter radius. For lightness, of course, is of primary importance to the aeronant. Further, when he has determined the length of his wing-arms, he will consider whether it will be more convenient to arrange the required area of sail-web as a single pair of wings, or as several pairs of smaller appendages ('vegetative repetitions'). Finally, if he decides on the latter method of organisation, he may attach all the flying limbs together by links, so that they may all be driven at once in the same directions by one engine or pair of engines, or he may contrive that they shall make their beats alternately or in succession, so as to make the forward effort of the moving power as nearly as possible continuous.

Of rotary vanes I have little to say, either of the direct-action feathering paddle, or of the oblique sail, or screw-propeller.

The feathering-paddle is, of course, nothing but an arrangement of several wing-wafts on a circular frame, so that a continuous impulse shall be obtained by the stroke of each in succession, while the others are, in turn, in process of feathering. The unintermitting action would certainly be an advantage, but it must not be supposed that a pair of alternately striking wafts would necessarily impress a jerking motion on the vessel. The air-craft must consist of a very considerable mass of matter, which it will take some time to set in motion, and some time to bring to rest. It will supply for itself the function which a fly-wheel executes for a steam-engine, keeping up its motion during the intervals of the return stroke, and reducing the periodical impulses of its wings to a more or less completely uniform pressure from behind. The chief objection to this form of propeller is that unless the wings are long,—that is, in this case, unless the diameter of the paddle-wheel is great,—the effect of the vanes or sails will be wasted to a great extent in creating a vortex in the air, instead of in pressing it steadily backwards.

And if the radius of the wheel is made considerable, the difficulty of construction will be very great, and the weight of the propellers will become a serious matter. For it might be impossible to find room among the rigging for the revolution of a large wing which could oscillate freely to and fro on the outside of the vessel. And even if it and its fellows in series could be accommodated with an orbit for their gyrations, the quantity of stays and framework necessary to give strength to the system of wings would render the wheel a very ponderous and unmanageable appendage. It must be remembered that, there being two planes perpendicular to any given plane, each of which is perpendicular to each other, there are two modes in which the vanes of a rotary wing may feather. Firstly, they may adjust themselves by making a partial revolution on an axis lying in the direction of a radius; secondly, they may shift themselves about a line at right angles to the radius and to the tangent of the circle of revolution. The former is perhaps the easiest form of construction, and the least likely to get out of repair.

The oblique sail, or screw-vane, is a genus of propellers more likely to be practicable. When it has been determined which of the numerous species of which it admits is the best for water, it will perhaps be enquired of nature by experiment whether the windmill sail, the smoke-jack, or a continuous curved surface, is the most promising form for aerial propulsion. In considering the case of these propellers, the same principles that must regulate the formation of the direct-striking wing must be kept in sight. The required resistance may be obtained either by making the area of the vanes large, or by giving velocity to their motion. And, as before, the speed may be enhanced by increasing either the rate of rotation, or the radius of the vanes. Length of the latter is unquestionably the quality on which most reliance should be placed. For a screw-wheel, revolving with great velocity, must, notwithstanding the inclination of its surface, throw off the air which it strikes in all radial directions by centrifugal force, thus lessening the density of the fluid upon which it strikes, and impairing the direct propelling effect due to the force resolved parallel to its axis. Again, the parts of the revolving sail that lie nearest the axis will be of but

little use for propulsion, and may even produce resistance in the backward direction. Whatever, then, may be the form of the vanes, or the angle at which they may be set on the shaft or spindle of the screw, they ought clearly to be arranged at a certain distance from the axis of revolution, supported upon naked rays or spokes not engaged in the sail-web, as in figs. 151, 152, 153.

Fig. 151.

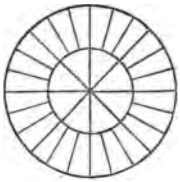


Fig. 152.

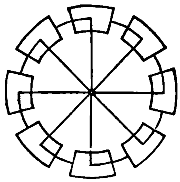
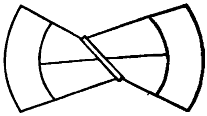


Fig. 153.



The experiment should also be tried of enclosing the screw-wheel co-axially within a hollow cylinder of canvas, just large enough to allow it to revolve freely. It is probable that this contrivance would favour the action of the screw considerably, for whatever air might be thrown outwards by the centrifugal force, would be retained within the stroke of the outer borders of the vanes, where their impulse is most effective, instead of being thrown beyond their reach. And thus the whole of the air which was struck by the propellers would be compelled to pass directly backwards, its whole reaction (except that which, being resolved perpendicularly to the axis of the screw, goes to resist its rotation) being available to urge the vessel forward. The form of the apparatus might be further varied, and probably with a beneficial result, by uniting the outer cylinder with the outer border of the screw, and causing the whole to revolve together. This would most effectually get rid of the centrifugal loss of force, and would reduce the condition of the propeller to a case more closely analogous to that of a screw worming through a solid substance, or at least to that of one moving in an inelastic fluid [1]

[1] This form of screw-propeller would be worth trying in water for propulsion, and both in water and in air for the purpose of pumping or producing a blast. It would be a very easy and simple experiment to enclose the screw-propeller of any ship, already fitted with such an instru-

It must also be determined by experiment whether a screw-vane constructed on the principle of Mr. Bennett Woodcroft's

ment, in a tube of copper plate, the tube being first tried as a fixed sheath enclosing the screw without touching it, and next as a case having the whole length of the outer edge of the screw joined to its inner surface, the cylinder revolving with the screw. There can be no doubt this form would be as well worth 'patenting' as many of the supposed improvements of the screw propeller. If a screw will drive a solid body through the water, it will of course also propel the liquid through a tube. Pumping and propulsion are, as I have said before, converse operations. The simplest of all possible pumps would undoubtedly be a tube containing, in some part of its length immersed in the liquid or fluid to be moved, a spindle having wound about it a spiral surface, in short a screw propeller of diameter nearly equal to the calibre of the tube. This spindle being made to revolve would propel the water through the tube in either direction, according as it were turned to the right or to the left. Such a pump would require no valves, and could scarcely get out of repair. It would probably be as powerful an hydraulic agent as Mr. Appold's now world-famous centrifugal pump. It would answer equally well as a bellows for an air blast, and conversely for taking power for driving machinery from a fall or current of water. In the latter case it would obviously be nothing but an application of the wind-mill principle to water. All these applications may be old, but not having met with them I must be excused the suggestion. It is probable that a misconception about the screw of Archimedes may have prevented the screw propeller from having been applied to pumping since it came into use for propulsion. It is known that the true Archimedes screw is not an economical mode of applying power to the raising of water, and the screw propeller has been called the Archimedes screw. Now the apparatus of Archimedes, though it is a spiral surface, works on a principle altogether different from that of the propeller. It is not immersed in the water from which it draws, but dips into it at its lower end and lifts the water, which it picks up, discharging it in intermittent gushes at the top. It can only work when inclined at or about a certain angle, which depends on the pitch of the screw surface. Such an hydraulic instrument as I would propose would work equally well at whatever angle it were inclined, and would throw the water in a perfectly continuous stream.

If now it should be found that a screw working within a tube should do fuller justice to the force expended by the moving power than does an exposed propeller, it would be an obvious step to place the screw within the body of the ship in a tube running lengthwise through it from stem to stern above the keel. There would be this great advantage in such an arrangement, that the thread of the screw might be made of any length

'Increasing Pitch Propeller,' would be more effective, than one constructed without this adjustment.

Passing now to our third group of propelling appliances, which I would arrange together as continuous jets, we enter the class by a natural transition from the revolving vanes, through the fan-blast, or centrifugal wheel.

I believe this to be a most promising instrument for aerial progression. Experiment is necessary to determine the best form of the wheel for throwing off the centrifugal current. This point has yet to be learned; there is no doubt that the common 'blowers' will admit of very great improvement. Whether Mr. Lloyd's noiseless fan-blowing machine, which requires, as the advertisement says, 'but half the power of the common fan to discharge the same quantity of air at the same pressure,' is the best that has yet been made, is perhaps already ascertained; at any rate whether it is the best that can be made, experiment must determine. Two things however are certain: first, that whatever fan-wheel is the most effective for producing a blast at

that might be requisite to give the fullest effect to the action of its surface upon the water, and to take full advantage of the principle of increasing its pitch with the addition to its length. By the way, a very simple and effectual method of lifting water by means of its adhesion to an endless flat band travelling over pulleys, one of which is in the well and the other at the point at which the liquid is to be delivered, might be applied to the propulsion of vessels on water. An endless canvas web running fore and aft along the vessel, and over rollers at each end, its lower half being immersed in the water and the upper in the air, entering the water at the bows and quitting it at the stern, would, by its adhesion to the liquid when in rapid motion, receive sufficient resistance to propel the vessel. There can be no question that this would be the case; is it not worth trying whether the result of so cheap and simple an arrangement would repay the power applied? The only power lost would be that expended in lifting the water which adhered to the web from the lower to the upper roller at the stern of the vessel, where it would be thrown off by centrifugal force. This would be reduced to a minimum by placing the upper channel for the forward passage of the web as low down as possible, consistently with its being above water. And the ratio which the power effectively employed should bear to this loss would depend upon the length of the web which was immersed in the water. It would be almost infinitely great in a ship a mile long.

a fixed point, will also be the best for aerial locomotion; second, that however good may be our inventions, we are never likely to get the best of anything till co-operative experiment by picked men for the social purpose of public benefit, is substituted for the competitive adventure of rival producers for private advantage.[1]

[1] As the waters are the 'fons omnium viventium' so our artificial organisms are usually developed in their aquatic application before they are adapted to the air. This, however, has not been the case with either the oblique vane, or the centrifugal wheel, which had grown respectively into the wind-mill sail, and the fan blast, before the screw propeller and the centrifugal pump had been heard of. However, now that these forms of mechanical life have taken fairly to the water, a far greater amount of labour has been expended on attempts to improve them than ever was bestowed upon their aerial analogues. And it is probable that perfection will be reached in the adaptation of them to the liquid, before the final steps have been taken towards fitting them for all the work they have to do in the elastic fluid. However, that the best centrifugal wheel that can be made has not yet been worked in water is rendered probable by the fact that three forms of it, all recently claiming excellence, have been exhibited at the great congress of art during the summer of 1851. The victory of Mr. Appold's rotary pump over its American competitor, does not of course prove that it is the best that can be contrived, only that it is very good. The fact of its superiority is a triumphant answer to those who assert that nothing but the privileges of monopoly will tempt men to invent, for its contriver has not secured to himself letters patent for the enjoyment of it.

I must be allowed to remark in continuation of my last note that it is a great pity that Mr. Appold does not endeavour to apply his centrifugal disc as a propeller for ships. The method of pump-propulsion has often been suggested: an instance of it is a model by Mr. Ruthven in the Great Exhibition (September 1851) (Class VIII. No. 171), but justice has never been done to the notion. For those who have proposed it have neither been at the pains to find the best possible pump for the purpose (that is, the one working with the least amount of friction of its own parts or of the water carried through it), nor have they arranged their pump-channels so as to obtain the result of the whole available force in the required direction. They have generally been content to direct the discharge end of the pipe towards the stern of the vessel, or towards the head when retrograde motion should be requisite. This has no doubt arisen from the belief that the escaping stream would move the vessel solely by the reaction due to its impact against the liquid without. Now even if this were the case with a jet of steam issuing from a closed vessel into the

The fan-wheel must be enclosed in a box or case, which may be of very light materials, provided only that its outer circumference, which will receive the pressure of the air, is airtight and sufficiently strong. This case may be made of canvas stretched on cane, the outer or peripheral part being oil-varnished. It must communicate with a canvas channel running fore and aft, so that the air may be both drawn in and expelled directly in the line of motion. The air-ways by which the fan blows through this channel must be double, so that by opening and shutting a pair of valves the current may be made to pass either from the fore end of the tube to the centre of the fan, and from the circumference of the latter to the after channel, or in the reverse directions. It is evident that by a proper adjustment of blast-channels, the same fan-wheel may be made to lift the vessel or to cause it to fall, and that it may be steered in a horizontal plane by simply altering the direction in which the fore or after mouth or vent of the air-channel is presented: for this purpose one of the ends of the tube would be made flexible.

air, it would not be true of a current of water or air drawn through a vessel open at both ends. In such a system the traction exerted on the vessel by the force which draws the liquid or fluid into it is fully as great as the propulsion exerted on it by the force which throws the same matter out in the opposite direction. Unless then the water that is to be ejected backwards be sucked in at the front of the vessel, through a pipe opening forwards, half of the force available for propulsion will be wasted. It is essential then that a pump-propeller to work efficiently must be connected with a pipe of which the mouth opens forwards, and the jet vent discharges towards the stern. The water in its passage through the vessel must be subjected to the least possible amount of friction. The tube must therefore be as nearly straight as possible, and must be as wide as can be conveniently permitted. A centrifugal disc of the best construction revolving in a box connected with this tube would form as compact and probably as efficient a propelling mechanism as any that could be devised. It is probable that in such an apparatus none of the power applied to it is lost except that which is absorbed by the friction of the water against the sides of the channels through which it is driven. The water-way should be fitted with two sets of valved channels leading to and from the chamber in which the rotary disc works, so that without stopping or reversing the engine the direction of propulsion may be at once changed by simply shutting off the current of water in one direction, and allowing it to flow in the other by shifting the position of the valves in the water channels.

One of the great advantages attending the system of pump or jet propulsion in the air is that, however the force be generated, the direction in which it is applied may be instantly altered, without shifting the position of the actual instrument of motion, by a simple movement of the jet nozzles,—a manœuvre which may be instantly effected by the hand. With any other form of propeller, a direct vertical course which will often be required can only be substituted for head-ward movement, either by changing the position of the moving agents of propulsion, or by having recourse to a second set of flyers specially provided for this purpose. This of course applies as well to any other blast apparatus as to the revolving fan. From the latter instrument we pass to the consideration of other forms of wind-compelling appliances.

The whole family of bellows and air-pumps, viewed as possible instruments of propulsion, belong to the group which act by virtue of a jet or stream of air. Two explanations have been given of the mode by which such machines act as propellers. It has been maintained that their efficacy depends upon the reaction of the escaping stream against the fluid without. On the other hand it has been stated that the motion of such a system depends on a disturbance of the balance of pressure from within upon the walls of the vessel that is set in motion. The supporters of this theory urge, that during the action of the power there is an outward pressure equal in every direction exerted by the confined fluid on the sides of the vessel that contains it, and that when the nozzle is opened, and a jet escapes from it, that part of the inner surface is relieved from the outward pressure, so that there is on the opposite side an excess of unbalanced pressure which causes motion of the whole body in the direction opposite to that in which the jet escapes. In fact both explanations are correct, and are mutually resolvable into each other.

Now a jet propeller, of whatever kind, whether revolving as a fan, or of alternate motion as a pump or bellows, may be considered as a contrivance for making the strokes of a wing: both the direct and return strokes exert a propelling effect in one and the same direction. A pump is scarcely likely to be used for aerial propulsion, by reason of the weight of the materials of

which it must be made and of the friction of its parts. A double acting bellows is the form of instrument best adapted for our purpose. Of such contrivances one of the lightest and most effectual forms would probably be that of the 'Soufflets cylindriques à piston sans frottement,' of M. Enfer of Paris, shown in the Great Exhibition (1851), (France, 830). This instrument consisted of a cylindrical bellows, working within an outer cylinder of thin sheet metal, so that in whichever direction the movable plate of the bellows is driven, it drives a current of air through the blast-pipe, either from the outer cylinder or from the bellows. In this apparatus, which works with scarcely any friction, the moving plate of the bellows may be considered as a wing, which towards whichever side it is striking puts forth the whole force of its waftage always in the same direction—this direction being determined by the position of the nozzle which guides the escaping air. Such a bellows fixed to the same rod with the piston of a steam or other reciprocating engine, would form a very light and simple propeller: the mechanism of the engine would be reduced to a minimum. The chief point would be to get the valves to act freely and rapidly, for they would have to be of considerable size so as to allow the air to pass with the least possible amount of resistance. Vulcanised caoutchouc would however easily accomplish this. For our locomotive purpose the outer cylinder might be made of strong oil-varnished canvas stretched on cane, if necessary strengthened with a network of split ratans, as likewise might the air-channels. These latter must be of such size as to give free passage to the air, their purpose being, not to concentrate the blast on one point, as in the forge bellows, but to guide it in a certain direction.

It is clear that the same kind of effect may be produced by the use of air-pumps of any form that can be used for generating a powerful blast of air. If any such apparatus can be adapted to our purpose, the best form will be a small pump with a very rapid stroke; for, though the friction would be greater, in proportion to the quantity of air moved, than with a large pump driving the same blast with a slower stroke, the lightness of the smaller engine would probably more than compensate for the loss of power.

But the fluid escaping from the jet-nozzle need not be air; may it not be steam? And if so may not we dispense altogether with the weight of machinery, and drive our air-craft by the mere escape of steam from a boiler? Undoubtedly we may. But whether we can obtain so high a velocity by this means, as by using the steam to work some kind of waftage-mechanism, is another question. Hero of Alexandria some 2,000 years ago, with his œolipile, gave to the first question an answer, which has been echoed in modern days by the American rotary engine of Avery, patented and praised in this country by Messrs. Craig and Staite. It has been abundantly proved that good work can be done by an engine worked by the escape of steam under high pressure from lateral jets at the extremities of revolving arms. And it has been asserted roundly that more useful effect was obtained from the steam by the same expenditure of fuel with one of these engines, than could be yielded by the piston and cylinder. If it were true that an engine worked on this principle, as a prime mover for machinery were economical of power, or even not very wasteful, there can be no doubt, not only that the same plan would be applicable to aerial propulsion, but that it would be the best form under which steam could be applied for this purpose. For of course the same force that will cause the nozzled arms of Hero's engine to revolve would confer rectilinear motion on a body free to move in air. If then a boiler suspended to a gas-float were armed with suitable jets, the mere escape of the steam from these in any direction would propel the whole system in a straight line in the opposite direction, would propel it not 45,000 feet in a minute, which was stated to be the most effective speed of the arms of Craig's engine—but at a certain velocity proportioned to the resistance to be overcome by the craft in its flight. And whether the jet be thriftful or wasteful of power, there can be no doubt that the speed attained by this direct resort would be greater than could be produced by the use of a rotary engine driven on this jet principle, and working wings or other mechanical propellers. For the same amount of power would be expended, and there would be no friction of machinery to consume any of it.

How much of the actual power due from the water evapo-

rated can be obtained in this mode of applying the steam, I have not been able to learn. I find numerous statements as to the efficacy of the rotary jet-engines,[1] and counter assertions of their extravagant inutility. But I have not met with any account of carefully made experiments, showing how many pounds can be raised a foot high per second per pound of water evaporated. It is generally believed, at present, that there is a great waste of power in this mode of using steam. I have not however seen the reason of this anywhere assigned. Theoretically it might seem that nothing could be simpler than this form of engine, except the calculation of the amount of power obtainable from it. Given the pressure of steam within the steam-pipe per square inch of surface, and given the area as an inch-fraction of the jet-apertures from which the vapour rushes out, the steam pressure on this area would be a statical measure of the force exerted in a direction opposite to that of the apertures. If this were actually the case, there is no doubt that this form of motive power would be as economical as it is simple. That however so much mechanical force, as is due on this hypothesis, cannot be obtained in practice, must be evident to anyone who has ever seen one of Armstrong's Hydro-electric machines at work. The enormous quantity of electricity given off by this apparatus is not obtained gratuitously. It is in fact so much dynamical converted into electrical force. This laboratory-lightning is extorted by friction out of the motion of the steam, and of the liquid particles carried with it.[2] It is obviously the immense friction to which the steam is subjected in being wire-drawn through the very small apertures from which it must be compelled to escape, that robs it of its power.

But even though this mode of using steam were too wasteful for ordinary use on earth, the extreme simplicity of the appa-

[1] See 'Mech. Mag.' No. 637 (1835), No 684 (1836), &c., and 'Craig's Patent Rotatory Steam-engine explained and illustrated,' p. 36 (1841).

[2] The writer of the eulogical pamphlet on Craig's engine just referred to had 'no doubt' that the electricity produced by the friction of the steam actually increased its power! (p. 24). The bounty of the Creator is profuse, but fair accounts are kept in the great co operative store of Nature. Profits are not measured there by self-interest.

ratus might render it serviceable for aerial purposes. For this end it might be worth trying whether surheating the steam in its passage from the boiler to the orifices would not, by diminishing its friction against the sides of the latter, increase the propelling force which it would exert. It is probable that by experiment it might be found that the friction of steam at light temperatures was less with some metals than with others. If so, by making the nozzles of the escape pipes of the metal that offers least resistance to the steam by friction, a further increase of power would be effected.

Failing in finding any information as to the useful effect obtainable from steam by the direct jet method, I had made a small copper boiler fitted with a short escape pipe, on the end of which nozzles of different sizes could be screwed, presenting the aperture in a horizontal direction; beneath the boiler was suspended by short links of wire a copper spirit lamp. This apparatus being suspended from the extremity of a light stiff rod, with a counterpoise at the other end, and the rod being balanced on a small glass cup resting on a blunt steel point, formed a machine representing in some respects the conditions of a steam boiler suspended from a gas-vessel. When the lamp was lighted and the water boiling briskly, the rod revolved on its pivot, the boiler and lamp flying round with considerable velocity. The limit of speed was very soon reached, however, for the faster it flew the more the lamp-flame was deflected from the boiler by the resistance of the air meeting it in its course. I therefore had fitted to the boiler a rounded shield, which, forming a cut-air in front, protected the flame within its concavity. With this improvement my flying œolipile behaved still better, whirling round at a speed of more than five miles an hour, when, the smallest nozzle being fitted to the boiler, the pressure therein was raised to about twenty pounds on the square inch. The larger the orifice of the nozzle the less was the speed obtained. As I had no convenient means of measuring the amount of resistance presented by the air to the moving system, or of ascertaining the amount of power exerted by the steam, further details of the results of this experiment would be useless.

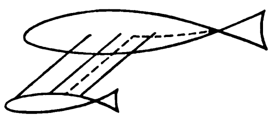
I subsequently had made a small apparatus with revolving arms for ascertaining the amount of propelling force obtainable from the steam jet, but it was not completed soon enough for the execution of the experiments I had devised. The result that would be produced by the steam jet as a propeller is, of course, exactly commensurate with its efficacy as an agent of ventilation. That a copious current of air could be made to rush with great velocity through channels such as the galleries of a mine by means of a jet of high-pressure steam issuing from a nozzle set in a main shaft, was long ago shown by Mr. Goldsworthy Gurney and Mr. Forster. Whatever advantages or inconveniences are found to be attached to this application of the steam would belong equally to its use as a direct instrument of locomotion.

If this rocket-principle is serviceable with steam, other substances which admit of rapid conversion into the gaseous state, with or without the direct use of fuel, may equally be applied as the instruments of waftage. Carbonic acid and nitrous oxide may be made to do service in this form, effectually perhaps, thriftily probably not; let experiment determine. That gunpowder may be applied in this manner is a very old notion, and has certainly been tried for water locomotion if not for aerial. If, however, the vapour-jet is to be used, other agents more tractable than gunpowder are available. And if rocket-powder is to serve us in locomotion, it may be harnessed to the work more safely and more savingly in a wing-working engine than as in Congreve's fiery 'horses, whose power is in their mouths and in their tails.' This I shall hereafter endeavour to show, for the consideration of this matter belongs properly to the subject of our next chapter; the 'power' to which it has been leading us by a regular and natural transition. For the rocket or steam jet being a particular instance of wafting-instrument, in which the agent is merged in the prime mover, lies necessarily on the confines of the two sections of the subject of propulsion.

Before, however, leaving this chapter we must provide our air-crafts with proper instruments of direction, that we may pleasantly vary the course along which we are being swept by our propellers. We shall require to alter our line of motion

horizontally and vertically. I have already stated my reasons for considering that we must not rely for the latter of these adjustments on a tail or rudder [1]; and have suggested the apparatus by which I believe it will be most effectually managed.[2] The kite-plane will be sufficient for all purposes of steering in the up or downward directions. A rudder, on the principle of the ordinary appendage of a water-boat, will be requisite for changing the course horizontally. A rudder attached to the stern or head of the boat will be sufficient for the ordinary air-craft. As the boat swings round in obedience to the helm it will turn the head of the gas-vessel with it. To ensure this the middle of the boat should be hung from a point forward of the mid-length of the gas-vessel. This will naturally be the case if the latter part of the system is built with a fine run aft; the greater cubic contents of its fore part will then, for the maintenance of the horizontal balance, require that the burden shall be slung nearer to the bows than to the stern of the float. The obedience of the gas-vessel to the rudder of the boat will be favoured if the former part of the system be furnished with an expanded tail fixed to its stern in a vertical plane. Such an appendage will increase the lateral pressure upon the after part of the float as soon as any change in the course of the boat throws the side of the gas-vessel against the air, and will thus leave the head free to follow the traction of the other vessel. But a complete and well-appointed craft, that it may be provided against all emergencies, should be furnished with means of turning as quickly as possible, and of guiding its gas-vessel with the greatest nicety to any given point. This would be secured by fitting a movable rudder to the float as well as to the boat, as in fig. 154. This appendage should be worked by cords carried round the body of the gas-vessel on pulleys to points on each side in the vertical plane, passing through the centre of buoyancy, and in the horizontal plane in which the sling-li[illegible]

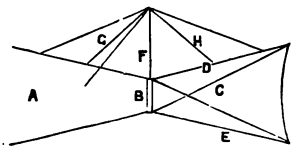
Fig. 154.



[1] P. 77.
[2] P. 409.

are attached. From these points these rudder ropes should be carried down to the boat in a direction parallel to the slings, as shown by the dotted line. Being wound round a barrel in the boat, on the same axis with that which carries the cords from the boat rudder, these ropes would be worked by the same movement by which the boat rudder is turned; and the two tails would move with perfect uniformity. The float-tail necessary for the guidance of a large gas-vessel would, of course, be a surface of magnitude; and with the framework of cane, or of metal tubes, on which it must be stretched, would be of considerable weight. To ensure therefore its working freely on its hinge, it must either be counterpoised by a weight attached to a prolongation of it on the other side of the pivots, towards the body of the vessel, or it must be slung from a mast or sprit fixed upon the stern of the vessel immediately above the hinge, and secured in its place by stays. The latter form, which is to be preferred as being lighter, and as involving a simpler articulation than the counterpoised tail, is represented in fig. 155. A is the stern of the gas-vessel; B, the rudder joint; C, the rudder-sail or tail, stretched between the bamboo-yards D E; F the mast or sprit for supporting the tail, by means of the stays G H.

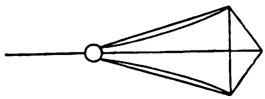
Fig. 155.



Nothing need be added about the boat tail. The manner of its construction is obvious. It may however be added that for such small craft as only carry one or two persons, are not charged with loose movable cargo, and, not being intended to soar to great heights, keep their gas-vessel nearly full, it may be practicable without inconvenience to steer in vertical directions by a tail. For in such a system there would be no danger of destroying the horizontal balance by shifting of the burden or the gas, when the vessels were inclined. The most serviceable rudder with which such a craft could be furnished would probably be a tail articulated by a ball and socket or universal joint, and consisting of two webs intersecting each other at right angles, as represented

in fig. 156. A single movement of such an appendage in any direction would effect at once a corresponding change in the course of the craft.

Fig. 156.



Our vessels are now completely rigged, and if we can only find a power adequate to the work of propulsion, will be ready at once to go to air.

CHAPTER XIV.[1]

CONDITION 12.—THE CRAFT MUST BE PROVIDED WITH 'POWER' SUFFICIENT FOR ITS PROPULSION.

I HAVE reserved this most important of our requisites for the end of my discussion, partly because it concerns the very life of my subject, partly because of the interesting nature of the matters to be treated of, partly because it has been much neglected by those

[1] The MS. ends abruptly in the middle of this chapter. The author, however, has drawn up the heads to be treated of in the chapter on 'Power,' which are here subjoined. ED. :—

Sources of Mechanical Power of two kinds may be considered—

(*a*) Those that work on the spot.
(*b*) Reservoirs of Force

(*a*) Divisible into—

1. Those that work by expansion.
2. ,, ,, contraction.

1A. Heat applied either to α fluids. ,, ,, β liquids. ,, ,, γ solids. α. Air Engines. Benzole—Explosive. β. Steam. Other vapours. Liquids which expand. γ. Expansion of metals. 1B. Freezing water. 1C. Wood-absorbing water. 1D. Sodium and water.	Those that work by expansion.
2. α. Electro-magnetism. β. Moistened rope.	By contraction.

who have touched upon Aerial Navigation, partly from the difficulty of properly handling it, and from a sense of the insufficiency of my acquirements. However, having kept up in the clouds so long, I shall at last do my best to achieve a descent with as little disgrace as may be.

Unless, as I have before remarked, the air-craft could be so put together that any force available and sufficient for its propulsion would when applied be really effective for that purpose, it would be useless to search among the powers of nature for one that should serve us. I believe that I have in the former chapters of this Part, pointed out how vessels may be built that will do full justice to any power that may be provided for them. We may now take a survey of such means of supplying force as we can find, and select those that may be most suited for our purpose.

I shall place before the reader in this chapter such methods of getting the work done for us as have occurred to me. I shall not endeavour to convince the reader by calculation that this or that or any source of power is sufficiently light to be used as the agent of propulsion for a gas-vessel large enough to float it, and a load of passengers and goods, on any particular scale of magnitude. It must be remembered that, however ponderous any given sort of engine may be, if it will work at all, and if its weight does not increase with its size far more rapidly than its power, there must be some limit at which the gas-vessel which is large enough to float it, will not meet with greater resistance from

(*b*) Reservoirs of Force divisible into virtually springs. To find the best spring :—

a. Mechanical.

1. Air ; will not do.	Tides.
2. Carbonic acid.	Winds.
3. Nitrous oxide.	Balloons.
4. Caoutchouc ; Steel.	Gravity.

β. Chemical.

Gunpowder moistened, &c.

Gun cotton.

γ. Vital.

Human muscle magnetised.

the air, at a required velocity, than the engine is capable of balancing. The lighter the source of power the smaller will be the scale on which the air-craft fitted with it may be constructed so as to travel with any required speed. The object of the aerial engineer will always be to find the lightest machinery for his craft. This will be more especially the case in the infancy of the art, when men will be endeavouring to build the smallest vessels that will fly. Hereafter, when successful experiments shall have given confidence to our aspirations, and we have learned that the larger their air-ships are, the more will they subserve a wise economy of material and of power—extreme lightness will not be so much insisted on as it must be at present. But in all ages a high ratio of power to weight will be a cardinal requisite in aerial engines. I have therefore looked about me for the lightest agents of mechanical force that I could find.

Another quality which will be very valuable in an aerial engine is that there shall be no constant and rapid loss of weight due to the dissipation into air of the material consumed. This is not an absolute necessity, since this loss may be compensated and the balance of buoyancy maintained, by a due discharge of gas from the float. I have pointed out in a former chapter [1] how an air-craft furnished with an engine entailing a constant diminution of its burden, could be made to effect this compensation.

Cheapness will be another requisite of the power: but in the present condition of the problem of Aerial Navigation, matters of price are not to be considered. The question is, 'Is this art possible to be attained?' not 'Is it expensive?' Whoever shall first fly direct from London to Paris, or even from Hyde Park to Regent's Park, and back again, at whatever cost, will have accomplished a great fact. What we want is the thing done. When it has once been achieved, subsequent endeavours will reduce the cost and increase the speed of its practice. I have therefore not considered the question of money price at all, power being the only coin with lightness for its stamp, and propulsion the only produce in the market in which lies my present business.

How then can we procure mechanical power? Can we

[1] P. 405.

make it—originate it? Never. We can but catch the life-spirit as it thrills restlessly, profusely, regularly, through the pulses of the universe, and direct it through the channels we can prepare for it. We ride upon a world which palpitates with 'Power,' swelling and sinking in eternal waves of Attraction and Repulsion,[1] or rather of Condensation and Expansion. There are ceaseless tides of condensation and expansion in the life of things, which taken either at flood or ebb lead on to Power. The generation of Power is as impossible as the creation of matter, is the same impossibility. Equally impossible is its extinction. Motion however may disappear. It may become latent, either being converted into some other phase of force, as when we grind lightning out of whirling glass, or being stored up in a quiescent state for a time, as when we compress a spring. In either case we are but saving the force, which the endless bounty of the Great Engineer supplies to us, and disposing it for a season as to us, or to Him, seems good. And the very force which we apply, whether of our steam-engine, or of our arms, whence comes it? from the fire or the flesh, not as from its fount or primordial source, but as from the terminal spout from which it flowed at last. It was stored up in the coal, and in the brain, as the result of the decomposing energies of ancient plant-life and of the up-building labours of the animal life of yesterday: each of these forces being but the ephemeral stages of the everlasting motion.

We may then either clutch the forces of nature as they fly, and harness them to our machinery for instant service, or we may seize them and bind them in fetters to do our bidding at

[1] Attraction and repulsion are very convenient words, but they imply more than we can assert, or have any right to assume. We know nothing of bodies drawing others to, and driving others from themselves. Motion to and motion from is all we see; an evergoing of one body towards or away from another. To say that the other attracts or repels it is but to shift the centre of the mystery, not to explain it; perhaps it is also to complicate our material for thought by introducing a new element more difficult to conceive than the essence of the simple fact which we see—the motion. The whole universe is instinct with life. The outward and visible sign of this life is motion. Men and things yearn and move hither and thither; we know not that they are attracted and repelled. God stirs them. 'I am the Life.'

other time and place, or we may find them ready locked in matter, waiting for our touch to release them to their work. In our wind and water-mills and sailing-ships we ply the first; in our clocks and watches the second; in our furnaces the third manœuvre. We have to enquire by which of these methods we can best adapt our resources to the Art of Locomotion through the air.

Of the first or free natural powers there is but one, so far as I am aware, that can serve us while in the air, and this may often oppose us:—the Wind of course. The heat of the sun may assist in lifting our craft by expanding the contents of the gas-vessel, but it would not be easy to apply his power to propulsion, even if his services could always be secured. From the nature of the case it cannot be applied to the working of our propelling mechanism, though it will, upon occasion, drive us and our mechanism together; we need not therefore consider its utility at present. We need only occupy ourselves here with the other two forms of resort. The second, the class of imprisoned powers, are, for the most part, to be unlocked by chemical means. And since to us, though not in fact, these natural reservoirs of force are practically fountains of energy, since we do not see them in action, till we as it were tap them and draw off their contents, they may be conveniently considered as 'natural sources of power.' [1]

[1] This division of our means of power into sources and reservoirs of force is not, it will be observed, founded on any real distinction, for the essential conditions of both are the same; both are reservoirs of the life of the world, as an egg is a reservoir of animal vitality. But it will be useful for classification. Neither would it be making a true difference between them to characterise the first as natural, the second as artificial stores of power, for there is no separation to be made between the natural and the artificial; the latter is but a particular case of the former. Nothing can be more false than the vulgar distinction between nature and art, and the pre-eminence in beauty and goodness usually assigned to the works of the former over those of the latter. This is in fact Atheism in its most disgusting form—that of cant. It implies the belief that God does not work by man's hands, though He does by wind and water. If there be any difference in degree, it must be that the works of human intellects are the more divine, as emanating from the highest of God's creative tools—the human 'beaver' brain.

The third class of forms in which we may employ force seems specially adapted for our purpose. Most of the means to which we can resort for obtaining power involve either fixed apparatus, as do those of our first class which were just now mentioned, or the use of ponderous appliances, as many of our second class. It becomes then very important for an art in which lightness is of prime necessity, to enquire whether we cannot store up in forms more portable than those with which the untamed world provides us, the forces which we can win or wring from it by these former methods. The problem put to the aeronaut by this consideration will be, how to travel through the air, having all the heavy work done on earth—to get, in short, his propulsion done at home before starting. The wound-up spring is the type of such appliances as we are thus led to search for, which may be called artificial 'Reservoirs of Force.'

First then of our 'Natural Sources of Power,' Heat and Chemism are the two forms of the nature-pervading force, which are most readily converted into dynamical motion. Both of these forces are ordinarily obtained as the result of the satisfaction of chemical attachment:[1] the species of energy which is developed depending on the conditions under which the transmutation of power takes place.

Heat is the condition in which force is most usually enlisted for our machines. Heat is the outward sign of a line of force, as measured in tune, just dipping to the bottom of its wave of condensation, and commencing to mount to its crest of dilatation.[2] We obtain therefore motion from heat, by virtue of the

[1] Commonly but improperly called chemical affinity. Affinity is the relationship of family connection, and is naturally predicated of such things as are similar in manner and feature. Attachment is an affection not necessarily founded on any such connection. Now chemical union for the most part depends on a love between substances of habits opposite and polar to each other, which do just not indicate affinity, but rather imply remoteness of relationship. This, however, is not the case with certain classes of compounds, such as metallic alloys and double salts; these are instances of family affection, of an attachment of affinity; but 'attachment' as a general term includes those last as well as the truly nuptial ties, such as that which binds iron to oxygen, and sodium to chlorine.

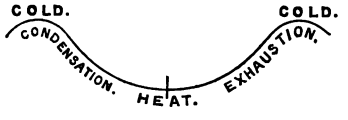
[2] 'The effects of what we call heat,' says Mr. Grove ('Correlation of

expansion of matter. The fuel by the burning of which we effect the condensation of matter which was previously expanded, may be considered as a reservoir of power, on which we draw at pleasure for the execution of our work. The first question then becomes, what is the fuel to be used? Now the obvious requisites in a material to be thus applied in aerial navigation, are these:—First, that it be all real fuel, that it consist entirely of substances that can help in the production of heat. It should yield therefore no waste ashes, and should contain as little as possible of combined oxygen. Second, it should be easily manageable, so that its consumption may be rapidly regulated, and its combustion extinguished or promoted at pleasure, while a constant temperature may be maintained, without the necessity of attendance. Third, it should burn in the manner most favourable to the application of its heat to the required purpose—that is

Physical Forces,' ed. 2) 'are simply an expansion of the matter acted on.' But this is not the whole of the phenomenon; heat is not caused by expansion: cold, or the neutralisation of heat, is always the result of expansion. That effect which our senses appreciate as heat has this relation to matter, that it is the ever-following result of condensation.

The typical instances of the development of heat are the compression of air or of any solid substance by mechanical force, and the process of combustion. In the former case, condensation of texture is the obvious event, heat is the appeal to our senses of the reaction of the expansion—the return of the wave. In the second case, the condensation of the oxygen that unites with the fuel is the effect of the chemical attachment, by virtue of which it rushes into combination. That dilatation alone is not heat, nor heat dilatation, is evident from the facts that the expansion of a volatile liquid into a fluid under the exhausting air-pump is accompanied by cold, and that the air condensed in a syringe is intensely hot. Cold is the result of expansion, heat follows condensation, condensation is the result of cold, expansion is the sequel of heat. Heat and cold, expansion and condensation, follow each other in eternal order. They are but different following arcs of an endless undulating curve. Expansion is the ascending, and condensation the descending, limb of the curve from the crown to the lowest dip. Heat is the lower, and cold the upper convexity, measured from the points of contrary flexure on the axis of the line. Thus (see fig. 157).

Fig. 157.



with flame. Fourth, it should occupy the smallest possible compass. Liquid fuel is obviously the best adapted to our purpose. The substances that fulfil all these conditions most completely are the hydro-carbon oils. These liquids, which are obtained at a moderate price from coal, consisting as they do entirely of true fuel, carbon and hydrogen, combine all the requisite qualities in the highest possible degree. The turning of a tap will regulate to the greatest nicety the amount of heat produced in the lamp-furnace in which they must be consumed. The products of their combination are nothing but steam and carbonic acid. They require for their perfect conversion into these gases that their vapour should be supplied to the flame in a state of intimate mixture with a considerable quantity of air.

This is very effectually accomplished by causing the liquid to flow into a small chamber, kept hot by the flame of the oil itself. In this chamber it is converted into vapour, which must be allowed to escape from it by a minute aperture, being forced out by pressure from behind. Naphtha lamps for light are made on this principle, in which the pressure is maintained upon the burner by the weight of a column of the liquid fuel itself, which descends from a reservoir at about 12 or 14 inches above the level of the flame. A furnace-lamp for the hydro-carbons may be more conveniently and safely constructed on the same plan as the common table fountains, in which the pressure is maintained by condensed air.

The reservoir of oil should be a strong metal box having only two apertures, through one of which a pipe passes, airtight, nearly to the bottom of the vessel, leading at its outer extremity to the burners. It is best that this aperture should be at the top, that the liquid may never be able to flow out at the burners, except when under pressure. The other aperture, which must be at the top of the box, should be fitted with a stop-cock and a small condensing syringe, or bellows, for forcing air into the vessel, for keeping up the pressure. The pressure required is but slight, and may be readily adjusted. This, together with a stop-cock on the pipe by which the liquid flows to the burners, will give the means of regulating the supply of fuel, and consequently the flame, to the greatest nicety. This pipe should be

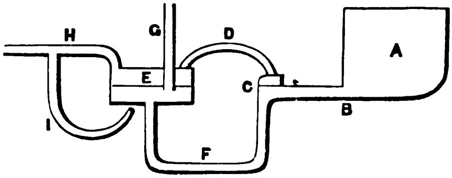
stuffed in some part of its length with tow, or some other porous matter, so that in case of an accident to one of the burners, the liquid cannot be forced out rapidly into the fire. No danger attends the use of such a furnace, for the reservoir may be below the level of the burners, and in case of any damage happening to the burner-pipe, the escape of the fuel would be instantly arrested by opening the stop-cock at the top of the vessel, and thus removing the pressure on the liquid. It will be seen that the little chamber in the burner is a small boiler, in which only so much of the fuel as is required for immediate consumption is heated, all the rest of the oil being kept cool. The vapour of the boiling liquid as it rushes through the small aperture into the air is mixed with the oxygen, so as to be effectually burnt without the production of any smoke.

Purified coal naphtha or oil of turpentine is usually burnt in lamps of this construction. But, with burners slightly modified, the cheap heavy oil of coal-tar might be consumed. This latter substance, though not consisting entirely of hydro-carbon, contains but a small percentage of other substances; it leaves of course no ash, though, some of its impurities not being perfectly volatile, a small residue of carbon would be left in the burner, which would require to be cleared out from time to time.

Another mode of burning the oils which are very rich in carbon, is by forcing a constant current of air through a vessel containing some of the liquid, and igniting the air at a jet or simple aperture at the extremity of the pipe by which it leaves the reservoir. The liquid must be kept at such a temperature that it will give off to the air flowing through or over it, a sufficient quantity of vapour to yield a good flame. The only liquid hydro-carbon which can be obtained in large quantities at present, that will behave thus at common temperatures, is benzole, which is one of the most volatile constituents of coal-tar. But other hydro-carbons, even those having high boiling points, may be consumed in this way if the vessel containing them is sufficiently heated, and the pipe conveying the vaporised air to the burner is kept warm, so as to prevent the condensation of its charge. If the jet be allowed to escape through a narrower aperture, a perfectly clear blue flame, giving an intense heat, may

be obtained in this way without the use of any chimney, from liquids which, burned in the ordinary manner, yield a dense white or yellow flame, with torrents of smoke. All that is requisite is, of course, that before the engine is started, a quantity of the liquid sufficient to afford a flame should be heated; the supply of vapour will be afterwards kept up by heat derived from the flame produced in the lamp-furnace itself. The current of air must also be driven by external aid till the engine has got to work; it will subsequently be maintained by a pump or bellows worked by a regular small tax upon the power obtained by the combustion. A form of apparatus in which this mode of consumption of the fuel may be practised without the danger or inconvenience of heating the whole stock of inflammable matter at once, is represented in the diagram, fig. 158. It is planned on

Fig. 158.



the principle of the common bird-fountain. A is the reservoir, a vessel of any convenient size, containing all the fuel required for the voyage. It has no opening except at B, where a short horizontal channel connects it with C. C is a small chamber in which a surface of the liquid receives the pressure of the air transmitted through the system. The function of C is to maintain the level of the liquid constant in E. This is effected by means of a pipe, D, connecting the upper parts of the two chambers, C and E, at points above the level of the oil in each, thus equalising the pressure of the air on the two liquid surfaces. E is the evaporating chamber, and is the only part of the apparatus which receives heat. The liquid is conducted to it from the fountain by the U tube F, the dip of which prevents any of the heated liquid from returning towards the reservoir. G is the pipe which brings the current of air from the blower. It passes through a stuffing box in the top of E, and dips a little way into the liquid:

by sliding it up and down in the stuffing box (this movement being permitted by making a part of the tube G of flexible material) the quantity of vapour taken up by the air, and therefore the heat of the flame may be regulated. From the top of E the air charged with vapour escapes by the pipe H, the mouth of which is sufficiently far above the liquid level to prevent any of the unevaporated oil from passing to the burners. The temperature of E may be maintained either by burning beneath it, or at its side, a small jet of the vaporised air, supplied by a small branch-pipe I, or by heating the air in the pipe G, on its passage to the vessel. The advantage of this form of furnace is that it is perfectly self-supplying, that the burners are simple jets, slits or holes, as for ordinary gas, and that nothing can pass into them, even if the fuel be impure, but really volatile matter, so that they cannot be liable to become clogged; all foreign substances must remain behind in the evaporator.

The fire being thus supplied, the next question becomes, what material shall we submit as the patient of expansion, and the agent of motion. Of the three forms of matter—solid, liquid, fluid, we may resort to either for this purpose. A single substance, in its transition from the second to the third of these states —water, steam—is almost the only one that has been turned to account in this service. The steam-engine has absorbed nearly all the practical ingenuity of the power-purveyors of this century, and the evaporated water has absorbed nearly all the available fuel-heat. Other volatile liquids have been proposed and tried as vehicles of power, but the many advantages of water have scarcely even allowed a hearing to the claims of alcohol and chloroform to be set to work. Engines to be worked by the expansion of heated atmospheric air, or of the gaseous products of the combustion of fuel, have been proposed from time to time. Sir G. Cayley has indeed made some experiments in this direction, with a special view to aerial propulsion. The expansion of liquids and of solids has, so far as I know, never been, even in attempt, applied to the working of machinery.

The common use of steam gives to aeriform fluids the first claim to consideration as vehicles of power. The two modes of applying the expansibility of matter in the gaseous state divide

the treatment of this part of the subject naturally into two heads: first, the conversion of liquids into the state of vapour; second, the expansion of substances already in the gaseous condition.

In the use of evaporation as a mode of applying power, there are two points to be considered: first, the liquid to be adopted; second, the mode of treating it. It is commonly supposed that it is a matter of indifference, in an economical point of view, as respects the expenditure of fuel, what liquid is used to work the steam-engine by its vapour: that, in short, no other liquid presenting any advantages over water, and water costing nothing, this substance is to be preferred to all others for the service. This belief is grounded on the fact that the heat as measured by numbers of degrees of the thermometer, which is converted into expansive force in the evaporation of certain liquids, commonly called the latent heat, is proportional to the volume of the vapour produced, so that the same bulk of vapour will be obtained by the same consumption of fuel, whichever of these liquids be used. It is assumed that this law holds good for all liquids. This however has not been proved. But there are two other points to be considered. Firstly, that it is very much easier, and more convenient, to obtain a rise in temperature of a given number of degrees low down in the thermometer scale, than it is to obtain the same increment at an intense heat. Indeed when the temperature of evaporation is very low, the whole heat required, being of low intensity, may be obtained from the atmosphere and surrounding objects. This is the case, for instance, with liquid carbonic acid, which since it rises into vapour under ordinary pressures, at temperatures considerably lower than that prevailing on the surface of the earth, and since it requires mechanical force for its reduction to the liquid state in the first instance, may properly be considered as a wound-up spring. I shall accordingly arrange this and substances having similar physical properties under the head of artificial reservoirs of force. Secondly, the specific heat of the liquids themselves, or the amount of heat-power which is required to raise the liquids before they boil, through a given number of degrees of sensible temperature, is of some moment. If this number for any given liquid is high, so much more heat is consumed in setting up

some molecular changes in the liquid itself before it evaporates, and this contributes nothing to the force available in the engine. Now the capacity for heat of water, or the quantity of heat which that liquid disposes of in this unprofitable manner, is far greater than that of any other substance in nature; and is double of that of some more volatile liquids which might supply its place in the steam-engine. Those bodies whose specific heat is low, are easy of condensation in the same measure as they are readily volatilized. This is another point which is favourable to their use in condensing engines. In engines from which the vapour is allowed to escape into the air, costly liquids are not likely to be used, as their consumption might more than compensate the saving in weight and expenditure of fuel, which their adoption might permit. When these latter engines are adopted, water is most likely to be chosen as the vehicle of force; except perhaps in early experiments on a small scale, in which the successful establishment of the method will be of more importance than the cost of material. In these attempts, which will be made on the smallest possible scale, the lightness of the apparatus being a point of primary necessity, any method of obtaining power, which is compatible with a small load of fuel, will be favoured. Chloroform and the highly volatile chloride of carbon, which, like water, have the valuable quality of not being inflammable, but, unlike it, require but little heat to affect their ebullition, are to be recommended for use. For aerial condensing engines, in which the agent of the power is not lost, or subjected to but a small waste, these less abundant liquids will be of great service, and are certainly to be preferred to water.

In considering the second of the questions just now stated as concerned in this discussion of the vapour-power—the mode of application—the nature of the engine is a point that presents itself for enquiry. Are we to fit our air-craft with condensing or with non-condensing engines? The former sort have the advantage of maintaining the weight of the load, so far as they are concerned, more nearly constant. But the much greater amount of weight which they involve in their construction, is such as to forbid their use except in air-craft of first-rate magnitude.

There is, however, a mode of applying the principle of the

condensing vapour-engine, which might be used with advantage for flight. If for water there be substituted a liquid the vapour of which is much more easily condensed, the advantages of a vacuum engine may be obtained, without the necessity of carrying a large quantity of water for the condenser. Further, the weight of the cooling apparatus may be very much reduced by substituting in it, for water, ice, with the further assistance of some salt for the production of a freezing mixture, and thus, of a very low temperature in a small compass of matter. The power of a condensing engine depends upon the alternate predominance in the agent which moves it, of heat and cold, and on the difference in the intensity of these two opposite forces in the two poles or foci of the system, the furnace and the condenser. Our object then is to raise this difference to the maximum. We may obviously attain this, either by raising the temperature of the boiler, or by lowering that of the condenser. In the ordinary condensing engine, the former plan is adopted, while we are contented with the common temperature of cold water for the cooling part of the operation. Now we may equally well effect the alternate expansions and contractions of the vapour, by concentrating all our artificial energy in the focus of condensation, trusting to the ordinary outer temperature for the evaporation of our liquid. This might be done with water as the subject of the changes of state, but much more readily with a liquid having a low specific heat, a low boiling point, and a low latent heat of vapour. Further, we can divide our weight between the two foci of our power, using a fire for evaporation and a freezing mixture for condensation; and by properly adjusting our available means to the end desired, and by duly distributing the work between the heater and the cooler, we may obtain the greatest possible effect, with the least amount of weight carried to effect it.

On the other hand, by using as our vehicle of force a liquid, evaporating only at temperatures very much higher than that of the air, absorbing but a small quantity of heat in evaporation, and giving out therefore but little in condensation, we may dispense with the necessity of carrying cold water or any other substance for condensation. The cooling effect of the air would

be abundantly sufficient for the condensation of the boiling hot vapour of some liquids. It may seem chimerical to propose to work an engine with the vapour of mercury, which boils at a heat but little below redness. But this substance might be applied as the agent of motion in a condensing engine, with quite as much efficiency as steam, and without requiring any water to be carried for its condensation. However, besides mercury, there are other liquids to be found in the fields of organic chemistry, with boiling points at any temperature that may be required below, and even above, that of mercury. One of these might be selected which would do the work which we require in this case. The disadvantages entailed by an engine worked in this manner would be the difficulty of keeping the moving parts vapour-tight, and the necessity of concentrating a very intense heat upon the evaporator, and the consequent rapid wear of that part of the system. This disadvantage, however, is to a great extent inseparable from the ordinary steam-furnaces, in which coal or coke is burnt, though it may be quite avoided by the lamp-furnace, which I propose when an intense heat is not required.

If such a liquid is to be used as, absorbing but little heat in the passage into the aeriform state, gives out but little in cooling, its condensation may be effected by receiving the vapour after its passage through the engine, in a system of tubes or a vessel having an extensive surface exposed to the full influence of the air which the craft meets in its flight. In a more compact form, the condensation may be effected by causing the vapour to pass into a receiver surmounted by a still-worm, which is enclosed in an outer pipe, connected with a vessel at top, containing a freezing mixture of ice and salt. The liquid running down from the freezing mixture would condense any ascending vapour that escaped liquefaction in the receiver, to which it would be returned in the liquid state. A great saving of weight would thus be effected, by carrying ice or snow, and salt, instead of water for condensation. There would be a peculiar facility in preserving the ice in the higher regions of the air, where a low temperature prevails.

Whether the engine be of the condensing or of the wasting genus, and whether the liquid be chloroform, water, or the

heavy oil of coal-tar, the construction of the boiler is a matter of the highest importance. This vital organ should be constructed[1] of small tubes containing the liquid, and receiving the heat on their outer surfaces[1]—tubular, not tubulated, as the locomotive boilers, usually called tubular, should be designated. The tubes should be arranged so as to allow the freest escape of the vapour, and circulation, if necessary, of the liquid. I recommend the reader to follow, as I have done, the advice of Mr. Armstrong,[2] and to read Dr. Alban's work on the high-pressure steam-engine. He will there find it proved that high pressure is the safest and most saving mode of using steam as an agent of power, and that, what is equally important for aerial purposes, it admits of boilers being made of thin sheet metal of great strength and of very little weight compared to that of the monstrous pachyderms, which at present are in power on earth and water, as their mammoth prototypes in the animal kingdom had their day by land and sea, in the infant ages of mammal growth.

By the use of very small boilers, into which, stroke for stroke, as much liquid should be injected as is consumed in each movement of the engine, a very small quantity being kept hot in the boiler, a very great saving in weight would be effected. The objection to the use of small boilers in general is, that the supply of heat power to the focus of evaporation is irregular, or at best intermittent, or periodical. In ordinary furnaces, which are supplied with coke or coal, the temperature is subjected to repeated lowerings by the addition of fuel, so that the great

[1] This was pointed out by Sir G. Cayley in 'Nicholson's Journal,' vol. xxiv. p. 166.

[2] Betaking myself to that one of Mr. Weale's excellent 'Rudimentary Treatises' that is entitled 'On Steam-boilers,' by R. Armstrong, in search, with especial reference to my present subject, of information as to the present practice and most approved fashion of boiler-making, I was much amused by finding myself thus recommended (p. 109) to consult Dr. Alban's book, of which an English translation is published by Mr. Weale. 'And to those who have serious intentions of promoting aerial navigation *by steam*, I would say this is the direction in which you must look.' It is certainly very creditable to a gentleman enjoying a high professional reputation on solid earth, that he should venture to speak of the great art of the future without a sneer.

mass of boiling liquid is necessary to play the part, as a flywheel to machinery, of a maintainer of the motion. With an unvarying flame-fire, such as would be obtained in a lamp-furnace supplied with liquid fuel, no such encumbrance would be required. The temperature on the outside of the boiler would be unvaried and constant; and if it were sufficient to generate the required quantity of vapour in the time occupied during each stroke or revolution of the engine, all that would be necessary to ensure perfect regularity of motion would be that the volatile liquid should be regularly supplied to it. By the due arrangement of the burners and of the boiler-tubes, the heat would be distributed so as gradually to raise the temperature of the liquid as it is pumped from the condenser to the boiler, to temperatures gradually increasing from that at which it leaves the condenser to that at which evaporation takes place.

It is obvious that, with such an arrangement for evaporation, scarcely any more liquid would be necessary to be carried, for supplying the boiler, than that quantity of which the vapour would fill the cylinder, or other vessel in which its expansion gives motion to the machinery, three times. If at any given instant, the cylinder is full of vapour, and the condenser contains the quantity of liquid formed by the cooling of one cylinderful of vapour, while the boiler holds enough liquid to supply the cylinder again with its gaseous charge, and the pipe leading from each vessel to the next is full of liquid or of vapour according to its function, all the requisites of continuous motion are ensured, so far as the vehicle of power is concerned. The only additional necessity is that the condenser should be cold enough to effect the complete and rapid liquefaction of the vapour, and the boiler hot enough to re-volatilize the liquid, as fast as the work to be done requires it. No further store of circulating liquid need be carried than is sufficient to supply the small waste which is unavoidable in the best engine that can be constructed.

The power of an engine supplied in this way will depend at any moment on the difference between the temperature of its furnace and that of its condenser, and may be increased or diminished by varying the conditions of either of these organs. It will be far easier with a lamp-furnace to regulate the heat,

than to alter the temperature of the condenser. By simply turning a tap, the heat about the boiler may be reduced or exalted at pleasure in a few seconds. The cooler then, if kept constantly fed with a regular supply of freezing mixture, would adapt its performance to the requirements of the engine.

To obviate the danger of priming, as well as to get rid of the inconvenience and burden of its usual preventive, a large separator, or capacious steam-room in the boiler, it would be advisable to pass the vapour on its way from the boiler to the cylinder, through heated tubes. By this means all the unevaporated liquid that might be mixed with the vapour would be volatilized, and thus its deposition in the cylinder would be prevented. With a condensing engine, such as we are now considering, a certain saving of power would be effected by this device, because all the heat carried in the liquid particles through the cylinder would be uselessly consumed in heating the condenser. But the saving would not be quite so great as in a non-condensing arrangement. It is obvious that with a lamp-furnace, by means of which every part of the apparatus may be heated exactly to the required point, there would be no danger of surcharging the vapour with heat too highly, so as to impede the working of the cylinder; and this can be absolutely prevented by passing the steam-pipe at the part where it is to be heated as a worm through a small bath kept constantly at such a temperature as may be required.[1] . . . .

. . . .

[1] For the means of keeping any such apparatus at any required temperature for any length of time, I beg . . . . .
. . . .

Here the MS. ceases. The following four pages, which were originally written in continuation of the note at p. 33, but were removed from that place without being relegated to any other position, are here added.—ED.

[This is really an extraordinary force,[1] apparently unlike anything else in nature, except gravity; and it does not seem to have been fully appreciated. But it really is incomparably superior to gravity in extent of application. We do manage to make a little use of gravity in our milldams and clock-cases. We do not make more of it because we cannot. We can get no fall. Our deepest mine-shafts and our loftiest precipices offer but a few thousand feet of fall, and if we used the first by letting weights run down them, we should fill them up, and quench the sources of our wealth; if we worked away at our mountain peaks, and sent them travelling into the valleys by rule and measure, they would be levelled in time, and the fallen weights would never come up to us again. And if we had pits ready made into the earth over its whole surface—if it were all pits except the places between them for men to work upon—there would be a limit to the pits in both dimensions—they couldn't be of greater depth than a certain shallowness, for the earth is liquid within, and could not have a hole in it; and they couldn't be nearer together than a certain distance, for they would be converging towards a centre, and a thousand bores would have but one bottom. Altogether other is the heavenward force of our mounting, heaving, hydrogen. Its field of action is boundless. Every point on earth is the mouth of an absolutely bottomless pit, stretching away into unfathomable space, ever diverging, the deeper it bores, the farther from any other line that can interfere with it. And down into this well that cannot be filled, we may pour the gigantic weight of a ninth part of the waters of the world, and the lightnings of the skies will fling them up to us again in rain.

For an illustration:—if I have a well fifty fathoms deep, and, being pressed for want of a little power, do not mind throwing a ton of earth into it, and so far filling it up, I can do so, and I

[1] The lifting power of hydrogen. [Ed.]

shall get a force on the surface equal to one ton raised 300 feet or of 300 tons raised one foot high; and this is the most I can make of it; and if I have not such a well I may go round all England, and not find a dozen so deep. But if I have a bulk of hydrogen that when I have put it in a bag which it does not more than a quarter fill, will lift the bag, a sufficient length of cord and a ton weight, I may let such my balloon fall upwards into the air to a depth or height of 30,000 feet, pulling to that height with the force of a ton, or doing for me work equal to 30,000 tons raised one foot high, and if my bag is bigger I shall get more power from my gas, the only practical limit being the size of the balloon, which must be large enough to contain all my gas as it expands.

I have been speaking of the use of hydrogen for this because it expresses a great deal in one word, and its lifting power is known. But we have a more convenient, readier, cheaper agent than the precious gas, and one equally capable of rushing up to the skies to do us service—heated air. This is the true mission of Montgolfier's magnificent invention. Its capabilities have yet to be developed. This is one of the points on which experiment is to be tried. What is the practical limit to the temperature, or degree of expansion that can be given by a source of heat to a bulk of enclosed air? What is the best source of heat? What the best material for the envelope of the air—the worst heat-conductor and radiator, that is in other points suitable for the purpose: the best therefore to prevent dissipation of the store of power within? These are economical questions, and admit of an easy reply by experiment. Should fuel be burned in the balloon, or should a body ready heated be placed within it? There is this possibility that the second may be the better method, that all the hot air thrown by it into the receptacle would be atmospheric air, and not a mixture of this air with heavy carbonic acid and condensible water-vapour. On the other hand, any such reservoir of heat might be too heavy in proportion to its charge of ascending power. This may be roughly calculated from the specific heats of various solids, as compared with that of air—and only *very* roughly, for it could not be determined, even nearly, what would be the real tempera-

ture of a heated body—for instance, of a white hot cannon ball. But experiment is the only road to certainty. If such source of heat were used, the mouth of the balloon of course would be closed to prevent loss of heat by radiation as far as possible, with a safety-valve below, to relieve the envelope in case of too great expansion of the air. If, however, fuel be determined on, there is I think little question as to what that should be. The requisite is, that it be the lightest substance containing in a given bulk the greatest amount of the elements that are burned by oxygen. These are of course the hydro-carbons. And the fuel must be in the most manageable form; this is another requisite fulfilled by these most serviceable compounds. They are nearly all liquid, and the liquid ones are very cheap. There is the oil of coal-tar, or even crude coal-tar itself, consisting almost entirely of available heat-making substance; no oxygen or nitrogen (at least almost none), and no ash. These substances are beyond question the fuel for all aerial purposes; their liquidity, the ease with which they are shut off or turned on the fire, and the precision with which, when requisite, their combustion may be regulated, mark them as sources of power especially adapted to the service of the aeronaut. However, this applies equally of course to this more stationary use, for which the objectionable name of 'Aerostation' may perhaps be admitted.

Before taking leave of this source of power, it may be mentioned that in addition to the gain of power by the employment of large balloons, which is common to all forms of aeronautic device, that the larger the vessel the smaller the proportional *weight* of surface to be carried; there is in this application another. This is, that the surface being proportionally less, there will be less loss of heat, and consequently of power, by radiation and convection by the external air.

The application of balloons filled with hydrogen and kept 'captive,' has been suggested by M. Marey Monge, in his 'Études sur l'Aerostation,' as a source of mechanical power. He proposes to avail himself of the diurnal differences in lifting power of a balloon caused by the access and withdrawal of the heat of the sun. He recommends that such balloons should be kept near the ground in connection with a certain excess of counterpoise

which they would raise when the sun shone upon them and caused their gas to expand; while, falling when they cooled at night, they would be ready next day to repeat the same manœuvre. He overrates very much the amount of power attainable, forgetting, firstly, that the sun's rays pass through gases without heating them,[1] so that all the heat the contents of the balloon would receive would be from the vessel itself by contact:—secondly, that the sun shining chiefly on the top of the balloon and heating its surface, it would only be the upper layers of gas that would receive any heat by conduction from the envelope, and these being thereby confirmed in their superior lightness, would stay where they were at top, while the lower parts would receive no heat.]

[1] This same remarkable oversight entirely vitiates an elaborate calculation about the lifting power of balloons, with which he has filled several pages of his most interesting book; and affords an apt illustration of a remark written in the preface, before I read the calculations referred to. The error is there coupled with a neglect of the fact that the contents of a gas-vessel must always be different from, and generally warmer than, the surrounding atmosphere. This must be the case because the outer air, as soon as it is warmed, is free to mount upwards, and is replaced by colder air from above. The confined gas is only cooled by radiation from the envelope, and by abstractions from its heat slowly made by the air in which it floats.—See Monge, 'Études,' pp. 253, 259.

As stated above, the MSS. abruptly ended at p. 479. But the author had drawn up 'A Sketch for a Treatise on Aeronautics' for the purpose of this work, in which the subjects for discussion in each chapter are noted; from this the chapter on 'Power' and the 'Conclusion' are here subjoined.—ED.

Point generally forgotten by aerial schemers,
Who content themselves with devising mechanism.
Sir G. Cayley almost alone has treated of this.
Steam—the most obvious.
Objections.
Not insurmountable, under *stated* conditions.
Modes of application. Liquid fuel.
Surheated steam.
Experiments to be made with gas as fuel.
Weight of engine.
Simplest case, no engine required.
Steam-jet,
Has been stated to be cheapest ventilator.
Probably, too, a very efficient propeller.
Avery's engine.
Rationale of action.
No good data as to power attainable.
Power reduced by *friction of steam* in jet.
The rocket principle generally.
High-pressure boilers.
Gurney's, Heason's, Alban's, &c.
Mode of application of steam direct to wings.
Alternate action at once.
Steam applicable to other propellers in usual way.
Other forces.
Expansion of heated air,
Proposed by Sir G. Cayley.

Benzole to be used as fuel in such engine.
Explosive mixtures.
Air passed through Benzole: ignited by Galvanism.
Alternately on opposite sides of piston.
Engine would pump its own air.
Electro-magnetism as a power,
Cannot lie fallow much longer.
No careful experiments made yet.
Hunt, Petrie.
Page's reported engine in America.
Reservoirs of force, as egg reservoir of vitality, (Parthenogenesis. p. 24).
Suggestion of contractile discs.[1]
Expansion of dry wood moistened.[2]
Moistened rope,
Used in quarrying.
How to be applied to machinery.
Expansion and contraction of metals.[3]
Enormous force; neglected by engineers.
Used to pull up inclined walls.
Of course applicable to drive machinery.[4]
Levers; lazy tongs.
Multiplying wheels.
The craft *started* to overcome inertia by stationary power.
Both expansion and contraction may be used.
If both, stronger bars necessary, not to bend, heavier.
If only the latter, wires may be used.
Strength of materials.
Mode of application.
Fuel-lamps; shifted to alternate bars.
Power very manageable; utterly dangerless.
Expansion of liquids,
Not quite so manageable.
Freezing of water.

[1] 'Mech. Mag.' vol. 36, p. 401.

[2] Herschel's 'Preliminary Discourse,' Introd. to 'Nat. Phil.' p. 48 (40) Ex. 5 (35) III.

[3] Electromagnets in 'Mech. Mag.' vol. 36, p. 101—vol. 54, No. 1, 1449–1450. Strength of iron bars. 'Mech. Mag.' vol. 47, p. 406.

[4] 'Mech. Mag.' vol. 31, p. 29.

Springs: to be wound up beforehand,[1]
May be used in connection with *above* forces,[2]
Or, with power exerted by stationary engines.

For gunpowder engine, Nitrate of Soda to be used instead of *Nitre*, because it does not burn so vigorously and explosively.

Parsey's compressed air-engine: only a spring,
And one in which power is lost.
No power lost in a good steel spring.
And very little in vulcanised caoutchouc.
Nothing known about the limits of springs.
By electrolytic or electro-power.
Decomposition of HO and re-explosion.
Coiled rope catapults.
Falling of weight (of whole car) from gas-vessel.
Water laid on—Reuvel.
Reservoirs of force.
Coal only a reservoir of force.
The Problem: to find the lightest.
Steam-engines to wind the springs up.
Waste of water powers.[3]
The Tides.
Enormous force utterly disregarded.
Might wind up springs, or
Liquefy carbonic acid: or nitrous oxide.
Gunpowder moistened.
Fire annihilator.[4]
Brunel—Cheverton.
Babbage's suggestion—the Geysers.
Sodium—another reservoir of force.
Either elastic, heating, or expansion of heat.
Might be made much cheaper.
Enormous quantities of it in sea-salt.

[1] 'Mech. Mag.' vol. 50, p. 208.
[2] 'Mech. Mag.' 1448, Shepherd's patent, p. 364.
[3] 'Mech. Mag.' No. 1446, p. 322.
[4] 'Mech. Mag.' vol. 51, p. 380.

CHAPTER XV.

CONCLUSION.

Apology for scheming and suggesting.
Vast field for experiment.
Weakness of isolated endeavours and experiments.
Proposal for Society or Association.
Sir G. Cayley's proposal formerly.
Hydrogen to supply leakages by Na. HO.
H. Power engine. The H. vessel not to open at top to air, but to gas-pipes.
Force not destructible.
Force not to be *made*, but to be kept.
The most to be got out of it before dissipating.
The Hydrogen to be *drawn* from gas-vessel, to put in ballast.
Exploded, to make water and give power, and *to fall.*
If wanted, resupplied by Na.
Filling up of the seas and lakes with hills,
An immense source of power.
Gas to be heated by Polmaise for rising.
Gas to be condensed by chemical attraction by C.
Self-acting water tap with barometer.
In case of sudden fall.
Rain-gutter, or eaves to gas-vessel.
Oil the gas-vessel.
Warmth of gas by heating will diminish dew as well.
Gas springs, five million cubic feet per day, in the valley of the Prehl in the Eifel. Carbonic acid.
Flax growth, its double use; oil and cloth.
Varnish in exhausted receiver.
Tussore-silk.
Vulcanised caoutchouc.
Zinc'd Iron.

Reduction of Iron-oxide, p. 125.

Hydrogen to be not more than twice the price of coke, equivalent for equivalent.

Gas-vessel never folded up will last longer.

If HSO_4 used, the sulphates to be distilled, or *precipitated.*

Experiments on equilibrium can be made with balance beam.

Part of cargo may be slung below the gas-vessel to maintain equilibrium by converging cords.

Fig. 159.

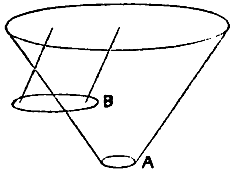
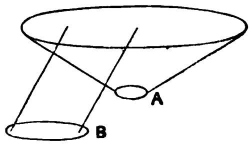


Fig. 160.



A. Burden ; B. Propelling power.

Arnott's Phys. I. 485.

Fine run of gas-vessel necessary,

Notwithstanding Scott Russell.

Arnott's Phys. I. 474.

Snake boats in *China.*

Simplicity of fountain.

Owen.

Complication of structure.

Diminution of *numbers* of pads.

The organic law.

Gas can't be carried forward by stoppage,

If envelope in outer case, full of air.

Gas-vessel (envelope) must have plenty of room for *expansion,* that it may rise and fall without loss.

Anchor-shackles.

Condition of anchoring same as of propelling.

Must not be a twisting force.

Two modes of doing.

Kite attachment.

Parallel—from centre of gyration.

Or an equator of gas-vessel, viz. from beak.

Must be able to anchor, however, not only when just floating,

But when vessel has rising power after landing passengers.

A balloon in equilibrium with air, may be shot up to any height by letting fall a weight, tied to a rope, which may be hauled up afterwards.

Experiments not to be made, as Monge and Cayley suggest, in brittle balloons, but by ascertaining facts.

Why not build a model?

No notice of Retur's dodge because not propulsion; refer to Sir G. Cayley, Edgeworth, and Evans.

Results of scientific observations—a few already.

The constant current—the two layers of rain clouds.

Heulk, Woser.

Man ought to navigate the air: all other animal classes have done so.

Why no mention of inclined plane and balloon ways.

Why second part a specification.

Do particularly want nobody to be able to patent.

Figures all in diagrams, as not completely fitted up in detail.

Addressed primarily to public, (like 'An. Mag.').

Secondarily, to engineers and men of science.

Why references made everywhere.

No more delicious floating in air-craft.

All the dangers in air *visible; not so at sea,* especially when coming to harbour.

Less danger of floating.

Burton's 'Anatomy of Melancholy,' part 2, sec. 1, mem 3.

Quotation from Ferguson, 'Beauty in Art.'

" Maitland, 'Mesmerism.'

A book of travels—the type book.

Resistance and Propulsion, 'Mech. Mag,' 1454, 486.

Blower to discharge gas if wanted in emergency.

Double gutta-percha film.

Experimental envelopes of thin paper.

Dupuis Delcourt and his Steam Gas Co.

Ammonia condensible by C.

Wing-wafts have same virtual effect to propel, at great altitudes, though *not to lift*, p. 127.

Effect of double casing to neutralise to some extent

Effects of change of temperature on gas.

Conclusion—that all the suggestions will work together (*vide* part 2; introd. p. 186).

Sir G. Cayley's proposal for a society, (Phil. Mag. v. 50, p. 28).

Conclusion—absurdity of making models before experimental researches as to data.

General notions as to the utility of the art; on the winds, currents, &c.

The Great Exhibition clearly made for experiments *hujus generis*.

Flying with kite—gas-vessel.

Every animal but man has flown—the fish, the lizard, the quadruped, the mammal, the insect, the bird.

APPENDICES

The Appendices were not prepared for publication by the Author, but have been drawn up from copious notes and memoranda on the different subjects treated of.—ED.

APPENDIX A.

List of books on Aeronautics consulted by the author. The first part consists of books quoted in this work, with the abbreviations for reference.

Books quoted.	Abbreviations.
'Philosophical Magazine'	'Phil. Mag.'
'Mechanics' Magazine'	'Mech. Mag.'
Monck Mason's 'Aeronautica'	Mason, 'Aeron.'
Faujas St. Fond's 'Experiences'	St. Fond, 'Exp.'
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APPENDIX B.

WEIGHTS OF MATERIALS, ETC.

		grains		grains	lbs. avdps.
Hydrogen, dry . .	100 cub. in.,	2·14 ;	1 cub. foot,	36·99 =	·0053
" moist[1] . .	"	2·334	"	40·34 =	·0058
Air	"	30·816	"	532·5 =	·076
Air, heated (as in fire-balloon)[2] . . .	"	20·544			
Light carburetted hydrogen	"	17·4166			
Water gas (CO_2 removed, sp. gr. ·500, from C. or Fe)[3]	"	15·408			
Ammonia (gas) . .	"	18·28			
Steam at 100° C. . .	"	19·2149			

1 gramme = 15·4336 grains = ·0022048 lbs. avdps. (log. 15·4336 = 1·1884673, log. ·0022048 = $\bar{3}$·3433693).

Buoyancy.

		grains		lbs. avdps.
Buoyant power of 1 cub. ft. hydrogen	=	495·5	=	·0708—dry
" "	=	492·1	=	·0703—moist

therefore to support 1 lb. avdps. (= 7,000 grains) 14·12 cub. ft. of H are required—dry

and 14·22 cub. ft.—moist

therefore if this be the true condition of moist H, the gain in buoyancy by drying will not be worth the trouble; for the gain for each cubic foot used, 3·4 grs. = for 10,000 cubic feet of gas only 4·857 lbs. avdps. Ure says it is usual to reckon that a cubic foot of practical H has a buoyancy of 1 oz. (he means apparently avoirdupois oz.).

Areas and Cubic Contents.

$$\pi = \frac{\text{circumference of circle}}{\text{diameter}} = 3{\cdot}1416$$

$2\pi = 6{\cdot}2832$; $4\pi = 12{\cdot}5664$; $\frac{4}{3}\pi = 4{\cdot}1888$; $\frac{\pi}{3} = 1{\cdot}0472$

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[1] Ure's Dict., p. 495.
[2] Cavallo, p. 128.
[3] Mech. Mag., August, 1850, p. 92, also p. 277 above.

log. π = ·4971498 ; log. 2π = ·7981798 ; log. 4π = 1·0992109 ; log. $\frac{4}{3}\pi$ = ·6220896

Circumference of circle $= 2\pi r$ (r = radius of circle)

Area of circle $= \pi r^2 = \cdot 7854 d^2$ ($d = 2r$ = diameter of circle)

Surface of sphere $= 4\pi r^2$ = area of 4 great circles = circumference × diameter [2] of great circles

Volume of sphere $= \frac{4}{3}\pi r^3 = \cdot 5236 d^3$

„ prolate spheroid $= \frac{4}{3}\pi a b^2$

„ oblate „ $= \frac{4}{3}\pi a^2 b$ $\begin{pmatrix} a = \text{semi-major axis of ellipse} \\ b = \text{〃 minor 〃} \end{pmatrix}$

„ cylinder $= \pi r^2 l = \cdot 7854 d^2 l$ (l = length of cylinder or cone)

„ cone $= \frac{\pi}{3} r^2 l$

Area of ellipse $= \pi a b$.

Resistance of Air to Motion.

Rouse and Smeaton's experiments give the resistance of air on plane surface bodies, moving in direction vertical to their surface, ·005 lb. per sq. foot, at the rate of 1 mile per hour, the pressure increasing as the square of the velocity; the pressure may be reduced to ½ or ⅓ of that due to sectional area by conical form of prow.

Expansion of Gases.

Gases expand $\frac{1}{480}$ (=·0020833) of their bulk for every degree Fahr. of the thermometer, commencing at 32°.

Specific Gravities.

Dry Hydrogen, referred to dry air as 1·00	= ·0694
Moist „ „ „ „	= ·0765
„ „ „ moist „	= ·0772
Coal gas—Vauxhall gas works[1] „	= ·412——·418

Weight of Balloon Materials.

August 24, 1850.—Weighed, in Ange and Aldred's fishing-rod shop, 126 Oxford Street, a piece of 'North Carolina' cane, 20 ft. long, about 1⅜ inch thick at butt end, tapering gradually off to a very small stick—weight of whole 1 lb. 10 oz. avdps. (16 oz. to the lb.).

A piece of hollow Malacca cane, ·21 ft. long and ·07 ft. thick at one end,

[1] Darby auct.

its bore, ·035 ft. at one end, and ·05 feet at the other, being cut between the knots, and very near the knot, at the end where the bore is least, weighs 11·256 grammes = 174·19 grains.

A piece of very thin brass tube, such as used by the fishing-rod makers for making joints for these cane-rods, the same length as this piece of cane, (if anything, shorter), and of just such calibre as to slip over the cane and fit it tightly; weighs 11·726 grammes = 181·05 grains; therefore cane is lighter, probably stronger, and certainly more elastic than brass tube.

Another piece of the same cane, ·11 ft. long, of same thickness as last, but of larger calibre, being cut from the same joint farther from the knot, weighs 4·58 grammes = 70·715 grains.

Another piece, ·135 ft. long, same average thickness, viz. ·07 ft., and *containing* the knot, weighs 8·169 grammes = 126·13 grains.

Weight.

Their solid cane (common yellow):—

		grammes	
A piece 8 inches long	=	7·86	
Another piece 8 inches long	=	6·15	
Mean	=	7·00	therefore per foot 10·5 grammes.

Another piece, thicker, 6 inches long = 9·77 grammes, therefore per foot 19·54 grammes.

Mean of 3 per foot, 15·02 grammes = ·033116 lbs., so that about 30 ft. of length weigh 1 lb.

Pieces of the wreck of Mr. Graham's balloon (burnt July 1850), carefully selected for freedom from injury by fire, and from paint:—

Weights		sq. ft.		grammes			grammes
A piece 12 inches square	=	1	=	16·726	=	per sq. ft.	16·726
„ 12 „ × 3 rectangle	=	$\frac{1}{4}$	=	4·0535	=	„	16·214
„ 2 „ × 1 „	=	$\frac{1}{72}$	=	0·2479	=	„	17·8488
„ 1 „ square	=	$\frac{1}{144}$	=	0·1353	=	„	19·4832
						Sum	70·272

Weight of square foot—mean of experiments is then $\frac{70{\cdot}272}{4} = 17{\cdot}568$ grammes = ·03865 lb. avoirdupois.

Therefore 25·873 square feet of this silk would weigh 1 lb. avdps. This silk is then considerably lighter than the thin varnished silk scrap from Darby, previously weighed, of which 1 sq. ft. = ·0432 lb.

White jaconet. (Macintosh's) cotton muslin, double, with caoutchouc between them :—

Weights		sq. ft.		grammes			grammes
A piece 2 inches square	=	$\frac{1}{36}$	=	·652	=	per square foot	23·472
Another piece 2 inches square	=	,,	=	·6075	=	,,	21·87
,, 1 inch square	=	$\frac{1}{144}$	=	·1555	=	,,	22·392
,, ,,	=	,,	=	·1575	=	,,	22·68
						Sum	90·414

Weight of square foot, mean of experiments, is then $\frac{90·414}{4}$ = 22·6035 grammes = ·049836 lb. avdps.

Weight of vulcanised caoutchouc sheet—mean of experiments.

		grammes		grains		lbs. avdps.
12 inches square, thinnest (No. 50)	=	44·017	=	679·62	=	0·0971
,, thicker (next quality)	=	71·3205	=	1101·2	=	0·1573

Weight of a piece of *unvarnished* goldbeater's skin (sent by Mr. Darby), made of two portions, joined by a glued seam down the middle of the length of the whole piece :—

A rectangle 38 in. × 11 in. = 418 sq. in. = 2·9 sq. ft.; weighs 6·89 grammes;

therefore 1 sq. ft. weighs 2·37 grammes = 36·58 grains = ·0052254 lb. avdps.

Darby says that for weight of varnish $\frac{1}{6}$ should be added = ·0008708, therefore the weight of 1 sq. ft. of prepared gold-skin for balloons will be ·0060962—say ·006 lb. avdps., therefore 166·7 sq. ft. will weigh 1lb.

Tussore si , light drab colour, in pieces 9 yds. long by 3 ft. 1 inch wide, 1*l.* 5*s.* 6*d.*—3*s.* 6*d.* per yard retail—Lewis and Allenby :—

	grammes		grammes		lbs. av.
Weight of piece 37 in. sq. (= 1369 sq. in.)	76·38	= per sq. ft.	8·034	=	·017713
Weight of piece A, cut from above piece, 24 in. × 13 in.	17·295 =	,,	7·982		
Weight of piece B, cut from above piece, 2 sq. ft.	15·76 =	,,	7·88		

Weight *per square foot*, mean of 3 experiments, $\frac{23·896}{3}$ = 7·965 grammes = ·0175 lb. avdps.

Corah silk—pale straw-colour—smooth surface—3*s.* 3*d.* per yard retail —Lewis and Allenby—in pieces 3 ft. wide (almost):—

	grammes		grammes	lbs. avdps.
Weight of piece 36 in. × 37 in. (=1332 sq. in.)	57·54	= per sq. ft.	6·2205	= ·013715
Weight of piece C, cut from above piece, 2 sq. ft.	12·39	= „	6·195	
Weight of piece D, cut from above piece, 2 sq. ft.	12·184	= „	6·092	

Weight per sq. ft., mean of 3 experiments, $\frac{18\cdot5075}{3}$ = 6·1692 grammes = ·013602 lb. avdps.

Mr. Bell's balloon silk, unvarnished, white—a beautiful close texture—(said by Darby to have cost 5*s.* 6*d.* per yard):—

			grammes		grammes
Weight of piece		4 × 3 in. rectangle	·5217	= per sq. ft.	6·2604
„	another piece	2 in. sq.	·1846	= „	6·6456
„	„	1 „	·0469	= „	6·7536
				Sum	19·6596

Mean from these experiments of weight of 1 sq. ft. 6·5532 grammes = ·0144485 avdps. lb.

Silk, said to be Mr. Graham's, unvarnished, white, not close, seems to be an inferior sort of Corah:—

			grammes		gramme
Weight of piece		6 × 2 in. rectangle	·49	= per sq. ft.	5·88
„	another piece	2 × 1 „	·0847	= „	6·0984
				Sum	11·9784

Mean of 2 experiments of weight of 1 sq. ft. 5·9892 grammes = ·013205 lb. avdps.

Varnished silk, said to be the same as Mr. Graham's balloon, that was burnt, was made from—and should therefore, saving the acquired dirt, oxidation or wear, be the same as last silk but varnished—seems tougher and closer, however:—

		inches	grammes		grammes
Weight of a piece		12 × 2 rectangle	2·2102	= per sq. ft.	13·2612
„	another piece	6 × 1 „	·5659	= „	13·5916
				Sum	26·8528

Mean from 2 experiments of weight of 1 sq. ft. 13·4264 grammes = ·029602 lb. avdps.

Experiments on Varnishing Silk.

Weight of the specimens of silk, marked A, B, C, and D,[1] after varnishing:—

	grammes		grammes		lbs. avdps.	weight of varnish per sq. ft. grammes
A. Thinly varnished	43·32	i.e. per sq. ft.	19·994	=	·044082	12·029
B. Thickly "	46·99	"	23·495	=	·051802	15·53
C. Thinly "	30·16	"	15·08	=	·033249	8·9108
D. Thickly "	35·59	"	17·795	=	·039233	11·6258

Taking B as the best sample, the weight of the varnish for a good balloon should be per sq. ft. 15·53 grammes.

October 19, 1850.—Sent these 4 pieces of silk to Mr. Darby to be varnished. A and C, with one thick coating, B and D with several thin coatings in D.'s best style.

November 20, 1850.—The pieces of silk sent home, I having written a few days before to enquire after them. They seem to have been but recently oiled, for they are not *perfectly* dry. Hang them up in the air for 3 days, then weigh them. The appearance of A and C is certainly different from that of B and D, the latter seeming to have more varnish, and a closer coat of it.

It appears by the weight that there is considerably more varnish in B and D than in A and C, respectively; there is also more varnish in A and B than in C and D. This is probably because the Tussore silk is stouter than the Corah, and therefore would soak up more varnish.

Goldbeater's Skin.

Gold-skin, cut from an old balloon (Darby from Weinling), half painted crimson:—

Weight of a piece convex about 4 × 4 inches rectangle ·2619 grammes = per sq. ft. 2·3571 grammes = ·0051969 lb. avdps.

Gutta-percha Sheet.

Sheet ·1 inch thick:—

Weight of piece 4 in. sq. 27·955 grammes = per sq. ft., calculated, 251·595 grammes = ·55473 lb. avdps.

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[1] Pp. 500, 501, above.

WEIGHT OF BALLOONS.

Weight of vulcanised caoutchouc sheet, thinnest,[1] 1 sq. ft. = ·0971 lb. avdps.
„ „ „ thicker „ = ·1573 „

Thin silk varnished with caoutchouc; a globe 1 foot in diameter weighs $\frac{1}{20}$ lb. avdps.,[2] therefore 1 sq. ft. weighs ·0519 lbs.

A piece of 2 sq. in., cut off a piece of varnished silk sent from Darby's, covering a bottle of his balloon varnish, which may be presumed to be a piece of balloon-silk, weighs ·2715 grammes = 4·2 grains: therefore 1 sq. ft. weighs 302·4 grains = ·0432 lb. avdps.

Weight of Green's great balloon, silk and apparatus (holding 70,000 cub. ft. of gas), 700 lbs. estimated.[3]

In Practice—(dic. Darby).

A balloon to support 1 lb. when filled with coal-gas should contain 50 cub. ft.

To fill a balloon holding 50 cub. ft. with hydrogen :—

Take a 50-gallon cask to generate the gas, and take a 10-gallon cask to wash the gas.

In the generating cask place 15 gallons (150 lbs.) of water, and with it *leaving to soak some time* 22 lbs. of zinc.

And to this add, about a pint or a quart at a time, 5 quarts (20 lbs.) of HSO_4.

This will make about 60 cub. ft. of gas.

2 or 3 inches of pressure on the pipe in the wash cask sufficient.

This formula is so far correct as to be on the safe side, for it supposes 69·4 lbs. of zinc to yield only 1 lb. of hydrogen, less than half that indicated by theory, according to which 32·6 lbs. of zinc should yield 1 lb. of hydrogen.[4]

According to Ure,[5] hydrogen acquires from water in contact with it an increase of nearly $\frac{1}{7}$th in specific gravity, becoming then about ·077.

Theoretically (e.g.) it will require 418·584 grains = 27·1 grammes of zinc to generate 600 cubic inches of hydrogen; and 1045·29 grains = 67·7

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[1] By experiment, p. 500.

[2] Encycl. Brit., Art. 'Aeronautics,' vol. ii. p. 182.

[3] Mech. Mag. 25, 395.

[4] According to my experiments 1 lb. of zinc yields about 5·2 cubic feet of hydrogen.

[5] Dict. Chem. pp. 495, 522.

grammes of zinc to generate 1,500 cubic inches of hydrogen; and 1255·76 grains = 81·33 grammes of zinc to generate 1,800 cubic inches of hydrogen.

Cavallo says :—

For 1 cubic foot of hydrogen take 6 oz. Zn., 6 oz. HSO_4, 30 oz. HO, all *by weight*, and he reckons such practical H as $\frac{1}{7}$th the weight of air.

Weight of paper balloon from Darby, made to my order (small model), 35·69 grammes, with, however, twice the number of gores requisite for my shape.

	grammes	
Weight of my smallest gold-skin balloon, empty	1·4917	grains 23·73
weighed again, Sep. 2 . .	1·478	
ditto. filled with breath .	1·5767	
,, second of C. M.'s	3·005	
,, largest { weighed again a month later (Oct. 31, 1850), 12·735 grammes; lightly varnished with olive-oil, 16·045 grammes; wiped finally with bibulous paper, 15·1 grammes. }	12·698	{ weighing at first, after being emptied of moist H, only 12·56 grammes, and gradually gaining in 2 days up to 12·709 gram., then returning to 12·698 gram., and then remaining stationary for half a day. (A fly in the balance.)

	grammes	grains	avdps. lbs.
,, paper balloon (2nd received from Darby)	383·38 =	5619·4 =	·80277
,, ,, (1st ,,)	419·25 =	6473· =	·925

Vulcanised Caoutchouc.

	grammes	
Actual weight of piece 12 inches square of vulcanised india-rubber sheet, not the thinnest (No. 22, i.e. $\frac{1}{22}$ inch thick)	68·61	{ (from a shop in Cheapside)
Actual weight of 1 square inch, ·519 from which calculated weight of 1 square foot . . .	74·736	
Actual weight of 2 square inches 1·004 . .	72·288	
,, 3 ,, 1·451 . .	69·648	
	4)285·282	
	71·3205 = 1101·2 grains = ·1573 lb.	

		grammes
Actual weight of piece 12 in. sq. of thinnest-made vulcanised india-rubber sheet (No. 50, $\frac{1}{50}$ inch thick)		44·705
Actual weight of 2 inches by $\frac{1}{2}$ inch rectangle I . .	·3072	
" " " " II . .	·297	
" 4 $\frac{1}{4}$ " . .	·2985	
	3)·9027	
1 sq. in. deduced as mean of 3 last experiments . .	·3009	
from which calculated weight of 1 sq. ft.		43·329
		2)88·034
Weight of 12 in. sq. mean of 4 experiments		44·017

= 679·62 grains = ·0971 lb. avdps.

APPENDIX C.

IS VULCANISED INDIA-RUBBER SHEET GAS-TIGHT?

A BAG made of thinnest vulcanised india-rubber sheet ('No. 50') of two circular pieces of flat sheet, 1 foot diameter, joined at their edges:—

	grammes
Empty, with the string used to tie it in next experiment, it weighs	66·73
Blown pretty full with air from bellows, and tied up with tape .	66·765
(The increase of weight probably due to slight condensation of the enclosed air.)	
Filled with moist Hydrogen under pressure of 11 in. water (400 cub. in. H thrown in, and tied up with same tape) . . .	59·36

September 13, 1850, 12 o'clock.—With this same charge of moist H, suspended to a thin string of vulcanised india-rubber, 6 in. long when not stretched at all; it stretches it to $11\frac{1}{2}$ in. The addition of 1 gramme to its weight increases the length to $11\frac{3}{4}$ in.; 2 grammes, 12 in., 3 grammes, $12\frac{1}{4}$ in. I find, however, that the vulcanised india-rubber string stretches permanently to a slight degree, for on removing the weights (3 grammes) immediately, the string remains stretched by weight of bag to $11\frac{3}{4}$ in.

It stretches a piece of the same caoutchouc cord 12 in. long to 21 in., which, by the addition of 1 gramme, is increased to $21\frac{3}{4}$ in.; by 2 grammes, to 22 in.; by 3 grammes, to $22\frac{1}{4}$ in. Permanent extension occurs again, for on removing the weights (3 grammes) the cord is stretched to $21\frac{1}{2}$ in.

September 13, 1.15 P.M.—Leave it hanging to the 12 in. cord, stretched to $21\frac{1}{2}$ in.

September 14, 9 A.M.—The cord has stretched to $22\frac{1}{2}$ in. On weighing I find it weighs 59·83 grammes, having gained in 21 hours ·47 gramme. This, however, is not enough to account for the stretching of the vulcanised caoutchouc cord, so I give up that mode of testing it; weighing is a little trouble, though it might be done by tying it to a vulcanised caoutchouc cord, and only hanging it at the moment of observation.

Weighed again Monday, September 16, 12 o'clock.—It weighs 60·97 grammes, having gained in 51 hours 1·14 gramme. The bag is now by no means tight, having evidently lost by leakage—whether or not by the tied mouth remains to be proved by another experiment, with more careful tying.

September 17, 11 A.M.—The bag weighs 61·41 grammes, having in 23 hours gained ·44 gramme.

September 19, 11 A.M.—The bag weighs 62·47 grammes, having in 48

hours gained 1·06 gramme. The bag is now quite flaccid, apparently about half full.

I now tie to mouth of caoutchouc bag, by connecting-tube, my smallest gold-skin balloon (which contains about 135 cub. in.), and fill the little balloon from the bag by pressure (there is plenty of gas left to fill it), and the balloon rises to the ceiling (though very slowly), and comes down again instantly; with *fresh* H it will only remain afloat for a minute. I judge, however, that but very little air had got into the bag; though H had got out.

I now refill the caoutchouc bag with moist H (from HCl) from gas-holder, under pressure of nearly 4 ft. 10 in. water, and weigh it, (it is tolerably tightly distended, but by no means strained); it weighs 57·84 grammes.

September 19, 11.30 A.M.—In this filling rather more than 400 cub. in. H are thrown in (as measured on the graduated gas-holder).

September 20, 3.30 P.M.—It weighs 59·09 grammes (not tense).

September 21, 0 M.—It weighs 59·93 grammes (less tense).

September 23, 2 P.M.—It weighs 61·34 grammes.

September 27, 4 P.M.—It weighs 63·12 grammes (half full).

October 3, 0 NOON.—It weighs 64·26 grammes (about a quarter full).

Another bag, of exactly same size and shape as last, of ('No. 32,' i.e. $\frac{1}{32}$ in. thick) vulcanised caoutchouc sheet, filled to tenseness. October 25, 1850, 2·30 P.M.—With about 380 cub. in. H. October 30.—Still tense. November 3.—Sensibly slack. November 6.—Slacker.

APPENDIX D.

CONSTRUCTION OF BALLOON.

We have now determined[1] the length of the whole gore, and the length of thirteen divisions of each of the two semi-prolate spheroids of which it is composed, and corresponding to twenty-seven points selected along the axis of the balloon, two of which points, viz. No. 1 and No. 27, are the fore and aft extremities.

The first two columns represent the lengths or distances to be measured on the length of the gore, beginning at the fore end.

The first column being the entire distance of each successive point from the fore extremity.

The second column representing the distances of each of the same measured from the preceding point in the same direction.

The third column gives the girth of the balloon at each measured point of the length of the gore, viz. the point in the same horizontal line in the Table.

From the numbers in this column the breadth of the gore can be deduced by dividing each number by the number of gores intended to be used.

The two final columns give the elliptic coordinates of the section of the balloon at the corresponding points, supposing the figure completed.

The unit of measurement in all is the radius of the greater circle, viz. that at the minor axis of the two combined spheroids.

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[1] The calculations from which this result has been derived, and which are of considerable length, are omitted.—Ed.

Table showing the dimensions of gores for the half-prolate spheroid balloon ($a = 4b$ & $a' = 8b$) in terms of minor axis of generating ellipses taken as unity.

Points on the gore in numerical order	Dimensions of gores: Distances along the gore measured from the fore end	Partial lengths along the gore measured to each point from the preceding one	Circular girth of the gore at each point	Corresponding dimensions of spheroid: Ordinates or semi-diameters measured at right angles to the axis of the balloon	Horizontal measurements or *abscissæ* measured from the centre of each spheroid along the axis of the balloon
1	0·000	0·000	0·000	0·000	4·000
2	0·044	0·044	0·275	0·044	3·996
3	0·090	0·046	0·435	0·087	3·984
4	0·137	0·047	0·820	0·130	3·966
5	0·187	0·050	1·091	0·174	3·940
6	0·302	0·115	1·626	0·259	3·863
7	0·436	0·134	2·149	0·342	3·759
8	0·771	0·335	3·142	0·500	3·464
9	1·195	0·424	4·039	0·643	3·064
10	1·704	0·509	4·814	0·766	2·571
11	2·283	0·579	5·441	0·866	2·000
12	2·919	0·636	5·905	0·940	1·368
13	3·595	0·676	6·185	0·985	0·695
14	4·289	0·694	6·283	1·000	0·000
15	5·678	1·389	6·185	0·985	1·389
16	7·026	1·348	5·905	0·940	2·736
17	8·292	1·266	5·441	0·866	4·000
18	9·439	1·147	4·814	0·766	5·143
19	10·432	0·993	4·039	0·643	6·128
20	11·245	0·813	3·142	0·500	6·928
21	11·857	0·611	2·149	0·342	7·518
22	12·082	0·225	1·626	0·259	7·727
23	12·257	0·175	1·091	0·174	7·880
24	12·325	0·068	0·820	0·130	7·932
25	12·383	0·058	0·435	0·087	7·969
26	12·434	0·051	0·275	0·044	7·993
27	12·479	0·045	0·000	0·000	8·000

APPENDIX E.

Table of dimensions, capacities, and other conditions of balloons formed of two half-prolate spheroids, in one of which $a = 4b$, in the other being $= 8b$.

Weight supported including balloon in lbs. avoirdupois y	Cubic feet of hydrogen	contained in balloon of form above described, having at its greatest thickness				
		in feet		in square feet		
(This column is independent of the form of balloon)	$\left(h = \frac{w}{\cdot 0684}\right)$	radius, $\left(b = \frac{\sqrt[3]{h}}{2\cdot 929}\right)$	diameter ($d=2b$)	sectional area ($s=3\cdot 1416b^2$)	Extreme length in feet ($l=12b$)	Entire surface in sq. feet ($f=60\cdot 008\ b^2$)
1	14·60	·834	1·669	2·19	10·013	41·78
2	29·20	1·051	2·103	3·47	12·617	66·28
3	43·80	1·203	2·407	4·55	14·442	86·59
3·42	50 00	1·260	2·520	4·99	15·120	95·72
4	58·40	1·325	2·649	5·51	15·900	105·35
5	73·00	1·427	2·853	6·40	17·122	122·20
6	87·60	1·516	3·032	7·22	18·195	137·91
6·84	100·00	1·584	3·168	7·88	19·008	150·56
7	102·20	1·596	3·192	8·00	19·154	152·85
8	116·80	1·669	3·337	8·74	20·026	167·16
9	131·40	1·736	3·471	9·46	20·828	180·84
10	146·00	1·798	3·595	10·17	21·573	194·00
10·26	150·00	1·814	3·628	10·33	21·768	197·47
13·68	200·00	1·996	3·992	12·51	23·952	239·07
17·10	250·00	2·150	4·301	14·53	25·809	277·64
20	292·00	2·265	4·530	16·11	27·180	307·84
26·96	(=14·6 c. yds.) 394·20	(=·8344 yards) 2·503	(=1·6688 yards) 5·006	(=2·18749 sq. yds.) 19·68	(=10·0132 yards) 30·039	376·56
34·20	500·00	2·709	5·419	23·06	32·517	440·71
50	730·00	3·074	6·148	29·68	36·889	567·04
51·30	750·00	3·101	6·203	30·22	37·222	577·42
68·40	1000·00	3·415	6·830	36 63	40·980	699·83
100	1460·00	3·873	7·746	47·12	46·478	899·64
102·60	1500·00	3·908	7·816	47·89	46·898	916·43
136·80	2000·00	4·302	8·604	58·12	51·624	1110·60
150	2192 00	4·435	8·870	61·79	53·220	1180·30
171	2500·00	4·633	9·267	67·45	55·604	1287·50

Weight supported including balloon in lbs. avoirdupois	by *Cubic* feet of hydrogen	Contained in balloon of form above described, having at its greatest thickness				
(This column is independent of the form of balloon)	$\left(h = \frac{w}{\cdot 0684}\right)$	in feet		in square feet	Extreme length in feet ($l=12b$)	Entire surface in sq. feet ($f=60\cdot008\,b^2$)
		Radius $\left(b = \frac{\sqrt[3]{h}}{2\cdot929}\right)$	Diameter ($d=2b$)	Sectional area ($s=3\cdot1416b^2$)		
200	2920·00	4·879	9·759	74·81	58·557	1429·70
205·20	3000·00	4·924	9·848	76·17	59·088	1455·60
250	3655·00	5·259	10·518	86·89	63·109	1659·60
273·60	4000·00	5·419	10·839	92·27	65·035	1762·80
342	5000·00	5·838	11·676	107·08	70·058	2021·80
410·40	6000·00	6·203	12·407	120·91	74·446	2317·50
478·80	7000·00	6·531	13·062	134·00	78·372	2559·60
500	7310·00	6·626	13·252	137·93	79·512	2634·60
547·20	8000·00	6·828	13·656	146·48	81·939	2784·10
615·60	9000·00	7·101	14·203	158·44	85·220	3026·70
684	10,000·00	7·355	14·711	169·97	88·266	3247·10
752·40	11,000·00	7·593	15·186	181·12	91·116	3459 60
800	11,695·00	7·749	15·499	188·67	92·995	3604·20
820·80	12,000·00	7·816	15·632	191·94	93 796	3665·80
889·20	13,000·00	8·027	16·055	202·46	96·333	3867·50
957·60	14,000·00	8·228	16·457	212 72	98·739	4063·60
1000	14,620·00	8·348	16·696	218·95	100·179	4182·10
1026	15,000·00	8·420	16·840	222·72	101·040	4254·30
1094	16,000·00	8·602	17·204	232·48	103·228	4440·30
1162·80	17,000·00	8·778	17·557	242·11	105·344	4624·80
1231·20	18,000·00	8·947	17·895	251·51	107·371	4807·00
1299·60	19,000·00	9·110	18·220	260·74	109·323	4980·30
1368	20,000·00	9·267	18·534	269·81	111·208	5153·40